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Absorbing and Developing Qualified Fighter Pilots

The Role of the Advanced Simulator

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Preface

This monograph documents RAND Corporation research on fighter pilot *absorption*, the process of ensuring that a pilot new to a weapon system gains sufficient experience with that system to carry out combat missions. After describing the role of the operational training environment in producing experienced pilots and the benefits of training with high-fidelity simulators in mission training centers (MTCs), we focus on survey results that show what factors, besides flying hours, contribute to the development of pilot experience. The surveys on which much of this document is based were conducted between October 2002 and October 2003.

The research reported here was sponsored by the Deputy Chief of Staff for Air and Space Operations, Headquarters U.S. Air Force (AF/A3/5); his counterparts in Air Combat Command and Air Mobility Command; and the Deputy Chief of Staff for Manpower and Personnel, Headquarters U.S. Air Force (AF/A1). It is part of a larger fiscal year 2006 study, "Aircrew Management Issues," conducted within the Manpower, Personnel and Training Program of RAND Project AIR FORCE.

This monograph should be of interest to those involved in the development of training and career management policies for the Air Force.

Related Publications

- *Absorbing Air Force Fighter Pilots: Parameters, Problems, and Policy Options*, by William W. Taylor, J. H. Bigelow, S. Craig Moore, Leslie Wickman, Brent Thomas, and Richard Marken (MR-1550-AF, 2002).
- *The Air Force Pilot Shortage: A Crisis for Operational Units?* by William W. Taylor, S. Craig Moore, and C. Robert Roll, Jr. (MR-1204-AF, 2000).
- *Models of Operational Training in Fighter Squadrons*, by J. H. Bigelow, William W. Taylor, S. Craig Moore, and Brent Thomas (MR-1701-AF, 2003).

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Summary

One of the main responsibilities of an operational fighter unit is to turn inexperienced pilots entering the unit into experienced pilots who are able to carry out the unit's operational mission effectively. The process of turning inexperienced pilots into experienced pilots is called *absorption*. The Air Force must manage pilot absorption to achieve two goals. First, it must ensure that operational units have enough experienced pilots to perform the unit's mission and to sustain the development of pilots for supervisory flying positions in the unit. Second, it must ensure that pilots gain the experience they will need to perform duties in nonflying positions that require rated officers.

Managing the absorption and subsequent development process effectively requires measuring pilot experience. Since pilot experience is developed through training in the unit's aircraft, it is currently measured in terms of aircraft flying hours; pilots with more flying hours are presumed to be more experienced. The Air Force uses the flying-hour measure of experience in its Rated Distribution and Training Management (RDTM) system as a basis for maintaining an appropriate mix of experienced and inexperienced pilots in operational units. The fundamental RDTM criterion for being identified as "experienced" is that a fighter pilot have 500 hours in the primary mission aircraft. Although the 500-hour RDTM definition is clear and quantitative, it may not accurately reveal actual pilot experience in terms of skills or qualification levels. The evidence is compelling that the quality of 500-hour pilots has varied considerably over the more than 30 years that the definition has been in use. These variations in pilot skills have changed

the quality of the operational training environment. Still, the RDTM definition has served the Air Force well despite these variations because it has historically provided aircrew managers with a useful measure of unit health in terms of pilot qualifications—the unit's *experience level* (the ratio of experienced primary mission pilots assigned divided by total primary pilots assigned). Embedded in the RDTM definition is the assumption that, if the unit's experience level remains high enough, pilots can continue to develop the skills and qualifications required to perform duties as instructors, supervisors, and staff officers. This assumption was quite valid when the RDTM definition was adopted, but evidence is growing that the absorption and development processes may have become decoupled and may require independent monitoring by aircrew and assignment-process managers. The problems result from inefficiencies caused by increasing numbers of inexperienced pilots and decreasing numbers of operational units.

One indication of possible inefficiencies in the absorption process is the stress on operational units lacking sufficient training resources to produce enough experienced pilots (see Taylor, Moore, and Roll, 2000; Taylor et al., 2002; and Bigelow et al., 2003). This stress is imposed, to some extent, by the RDTM definition of an experienced pilot as one with at least 500 hours in the primary mission aircraft. A more-accurate accounting of pilot absorption and development opportunities is required.

The present research was designed to examine how well the RDTM flying-hour measure of experience corresponds to expert pilots' notions of what constitutes an experienced pilot in terms of ability to perform additional tasks, such as staff or supervisory duties. To study what is meant by *experience*, it is necessary to be able to measure pilots' actual capability levels, which cannot be observed directly. Ultimately, the degree to which a pilot reflects an experienced ability level can be known only through subjective judgments made by peers and commanding officers. To determine the basis of these judgments, we developed a survey to determine the factors that contribute to judgments of pilot experience and development. These surveys were conducted between October 2002 and October 2003. Fighter training experts (supervisors and instructor pilots) judged the experience level of pilots

with different backgrounds and training experiences in terms of aircraft proficiency and readiness for a staff assignment.

The results of an initial survey conducted at an F-16 base indicated that flying hours are only one of the factors that contribute to judgments of a pilot's experience (see p. 62). Other factors include a pilot's previous flying experience, upgrade level, and types of training sorties flown (see pp. 63–64). These results suggest that the current approach to measuring experience in terms of flying hours alone may not accurately estimate a pilot's actual level of experience because it ignores many of the external factors that influence the development of pilot experience.

The results of a second survey conducted at F-15C bases having advanced simulator systems with MTCs capable of linked distributed mission operations indicated that certain types of MTC training, such as large-force employment exercises (which involve interaction among a number of aircrews in a simulated combat environment), contribute significantly to pilot experience in terms of combat capability (see p. 49). The results of the F-15C survey also indicated that experience is not a yes-or-no variable and must be considered in context. Having the experience necessary not to require special in-flight supervision, for example, is quite distinct from having the experience required to assume staff or supervisory duties (see p. 42). Our survey results indicate that unit supervisors believe the latter type of experience requires nearly twice the flying hours as the 500-hour RDTM requirement for experience (see p. 44). These results strongly indicate that the absorption and developmental processes for pilots need to be monitored independently for the Air Force to ensure its pilots have the opportunity to continue to develop required operational skills after their initial operational assignment.

The F-15C survey also asked about the optimal mix of sortie types required to maintain aircraft proficiency in terms of combat readiness. The experts in the F-15C units agreed that the optimal number of live sorties per month was about 14 (see p. 50). These experts also agreed that the optimal number of MTC sorties per month was about five. So the experts agreed that a total of about 19 training profiles (including live sorties and simulator missions) per month was optimal and that about

26 percent of these sorties should be large force employment exercises flown in the MTC (see p. 53). Clearly, these advanced simulator systems, as they become available, can be regarded as essential components of the operational training environment that can also contribute significantly to the initial absorption and ongoing development of experienced pilots.

The survey results suggest that it is time for the Air Force to consider revising its yes-or-no view of pilot experience to manage the absorption and development processes separately for both operational training and career progression (see p. 57). An additional measure of pilot experience will be necessary to reflect the skills and qualifications acquired to prepare for more-senior supervisory or staff assignments. The absorption process must still be based on some measure of experience, but managing development and subsequent career progression will require an additional measure that accounts for development of these additional skills (see pp. 57–58).[1]

With certain caveats, we also recommend modifying all experience definitions to include credit for appropriate training in advanced simulator systems with MTCs (see p. 57). This change would incorporate a very effective training opportunity in units in which it is available and could codify the training requirements and accomplishments necessary for a more-efficient mix of live and simulator training. Our caveats include the following:

1. Advanced systems should be available to all pilots working with given a mission design series.
2. Funding for fielding new systems, providing ongoing essential software updates for fielded systems, and continuing development of distributed links to other appropriate units needs to be adequate.
3. Training requirements need to emphasize and exploit an integrated and coordinated mix of live and simulator training.

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[1] The Air Force has recently established officer development programs in all career fields to ensure senior-level review of officer development options and opportunities. We are concerned, however, that this review process may not begin early enough for rated officers to ensure that all (or even most) of them can continue to develop the required operational skills in subsequent assignments after their initial operational assignments.

Acknowledgments

A number of Air Force agencies contributed significant amounts of information, data, suggestions, and encouragement in this effort. The authors would especially like to thank the operational training shops at the Air Staff (now AF/A3OT), Air Mobility Command (AMC/A3T), and Air Combat Command (ACC/A3T) for their continued support and assistance. Our appreciation for the capabilities of advanced simulators was definitely enhanced during meetings with simulator experts at ACC headquarters, Langley Air Force Base (AFB), Virginia; the Air Force Research Laboratory (AFRL), Mesa, Arizona; the Boeing Company, St. Louis, Missouri; and NASA Ames, Moffat Field, California. Chuck Colegrove at Langley and Winston R. Bennett at AFRL deserve special thanks for their support and assistance throughout.

Several RAND Air Force Fellows (Air Force officers who complete senior developmental education assignments by participating in RAND analytic efforts) also made significant contributions. Marc Dippold shared his operational F-16 expertise and helped us gain access to significant amounts of Air Force training information. Scott Davis' extensive fighter background in F-22s and F-15Cs was invaluable in constructing meaningful questionnaires for our surveys. Peter Hirneise's background in fighters, coupled with his previous experience working F-15C simulator development issues at AFRL in Mesa, was extremely valuable in our learning process as we examined the issues.

We also thank the ACC Director of Operations and the operations group commanders at Langley AFB, Eglin AFB, and Hill AFB for granting us access to the supervisors and instructors who responded

to our surveys. We must also thank the supervisors and instructors themselves for taking the time and effort from their busy schedules to carefully provide us with usable data.

Finally, we thank our RAND colleague, William "Skip" Williams, and our external reviewer, Gary Latham, for their thoughtful and useful reviews of our earlier draft. Their efforts definitely improved our presentation of the material.

Abbreviations

A/C   aircraft

ACC   Air Combat Command

ACM   air combat maneuvering

ACMI   air combat maneuvering and instrumentation

ACT   air combat tactics

AEF   air expeditionary force

AFB   Air Force base

AFRL   Air Force Research Laboratory

API   aircrew position indicator

ASD   average sortie duration

BFM   basic flight maneuvers

DOC   designed operational capability

DMO   distributed mission operations

DMT   distributed mission training

FY   fiscal year

MDS   mission design series

LFE   large force employment

MTC   mission training center

PAA   primary aircraft authorized

PMA   primary mission aircraft

PMAI   primary mission aircraft inventory

RDTM   Rated Distribution and Training Management System

SCM   sorties per crew per month

UTE   aircraft utilization

Introduction

Operational fighter units must provide the training necessary to turn inexperienced pilots beginning their initial operational assignment in a new weapon system into experienced pilots who can perform the unit's specific combat mission. This training must also prepare pilots to continue to acquire the skills required to fill rated supervisory and staff positions at the wing level and above.[1] The process of turning pilots new to a weapon system into experienced pilots is called *absorption*.

The Air Force must manage pilot absorption to achieve two goals. First, it must ensure that pilots new to a unit are able to meet the experience criterion within the time available in their initial operational flying opportunity. Second, it must ensure that units have enough qualified pilots to perform the unit's mission and to provide adequate in-flight supervision and instruction to the pilots in the unit with less experience and fewer qualifications. The latter requirement relates directly to helping officers acquire the additional operational skills and qualifications they need to fill the supervisory and staff positions that the Air Force has identified as requiring rated officers.

For several decades, the Air Force has used a pilot's flying hours as a measure of experience to manage both tasks through the Rated Distribution and Training Management (RDTM) system, which, as described in more detail in Chapter Two, defines an experienced pilot as one having 500 hours in the unit's primary mission aircraft. But the

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[1] The unit conducts training to help maintain currency in perishable skills, to provide opportunities to increase proficiency and operate in a wider range of mission contexts, and to help sustain unit combat capability.

developmental process clearly includes exposure to contexts beyond, and substantially different from, the experiences and situations encountered in a pilot's initial 500 hours of flying.

Chapter Two describes the operational training environment and changes in the *quality* and *quantity* of flying training since the 1970s that may undermine some of the original assumptions that made the RDTM system valid. In particular, the chapter discusses the importance of monitoring the relationship between the problems of absorbing individual pilots and of the unit's training and development.

Chapter Three describes the MTC training facilities and high-fidelity simulator systems that are now available in some fighter units and outlines how they can be used efficiently to provide certain types of training. Chapter Four describes the surveys we conducted between October 2002 and October 2003 to understand training experts' views of what constitutes experience in different contexts for pilots. Chapter Five discusses the implications of the survey results and addresses the aircrew management policy changes that these results suggest will be required.

The Role of the Operational Training Environment

Operational units provide the resources required for each Air Force weapon system to accomplish its primary mission. For fighter units, this means that aircrews assigned to these units must continually train to develop and maintain their combat capabilities. But operational units also have another important function: They must continue to sustain themselves by turning new pilots into experienced pilots and ensuring that they have the opportunity to continue developing into flight leads, instructor pilots, and supervisors.

The Training Environment

Earlier RAND Corporation work has addressed the degrading effects that low experience (inadequately qualified pilots) and overmanning have in all types of operational fighter units (see Taylor et al., 2002, and Taylor, Moore, and Roll, 2000). Other factors can also affect unit training effectiveness and therefore the development of new pilots. In the next few paragraphs, we will examine the operational training environment more carefully to better understand the causes (and effects) of some of these factors. Our purpose is to provide a useful framework that will enable us to examine more comprehensively the contributions that high-fidelity simulators and MTCs can make to the overall operational environment. For specificity, we will focus primarily on F-15C air-superiority units because they were the first Air Force fighter units to receive the advanced simulators and MTCs.

Training Basics

The fundamental training unit for fighters is a single sortie; each sortie is typically devoted to a specific mission need. These mission training sorties often build on one another inasmuch as the skills stressed in one type of training sortie will be essential components of more-complex training sorties. Figure 2.1 illustrates this building-block approach by using an F-15C air-superiority unit's primary training sorties as an example. *Advanced handling characteristics* sorties are the most fundamental of the building blocks. In such a sortie, the pilot flies a single aircraft, with no adversary, to fully explore the aircraft's maximum-performance maneuvering envelope. This develops familiarity with the flight maneuvers that will be required in an air-to-air combat environment. It also helps pilots recognize key in-flight indications that enable maneuvering at maximum efficiency and avoid departing from controlled flight.

The remaining training sorties each introduce in turn new skills that will be essential in an air-to-air combat engagement. *Basic fighter maneuver* (BFM) sorties, for example, stress the techniques needed for a single aircraft to maneuver successfully against a single adversary in a variety of settings, while *air combat maneuver* (ACM) sorties stress

Figure 2.1
Building-Block Model of Training Missions for the F-15C

Large-force employment (LFE)

Air combat tactics (ACT)

Tactical intercepts (TI)

Air combat maneuver (ACM)

Basic fighter maneuver (BFM)

Advanced handling characteristics (AHC)

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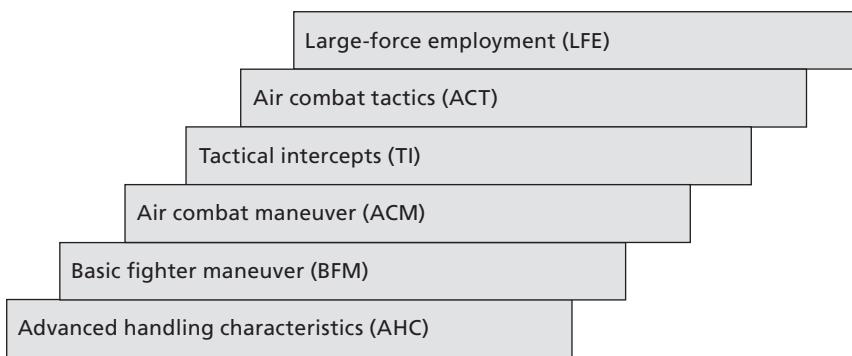
maneuvering a two-ship element against an adversary to maintain mutual support and fully appreciate a larger portion of the threat spectrum. Tactical intercepts enable four-ship flight members to master the essential cues, indications, and geometric relations for using radar and other nonvisual methods to sort, target, and engage a flight of adversary aircraft. *Air combat tactics* (ACT) sorties enable four-ship flights to explore a number of realistic combat scenarios against two or more adversaries. Finally, *large force employment* (LFE) exercises enable multiple four-ship flights to understand the specific roles and flight interrelationships involved in meeting all the responsibilities required for different kinds of specific missions. These preplanned exercises simulate realistic combat employment requirements.

Demands That Can Degrade Training Quality

An F-15C unit must meet other sortie demands that are not listed among the primary training sorties in Figure 2.1. Some of these provide essential training, such as instrument and ocean-crossing deployment sorties, and can be quite useful unless they are being performed merely because weather or other constraints have forced them to replace primary training sorties. Other sortie demands that one might expect to be useful can actually degrade training.

Contingency Operations
Flying requirements that support actual contingency operations, such as Southern Watch (flown in Iraq between the Gulf War and Iraqi Freedom), Noble Eagle (flown as post–9/11 homeland security support in the United States), and Enduring Freedom (flown in Afghanistan), can provide useful training initially, but participating pilots generally agree that the training can become quite diluted when the same missions are flown repetitively. A primary factor for air-superiority units, of course, has been the total absence of enemy fighters during these operations. Another factor is that the participating aircraft must be loaded with live ordnance, thereby significantly limiting the available

training options for these sorties and virtually eliminating the opportunity to use these sorties to conduct pilot upgrade flights.

It is important to note that flying hours devoted to contingency operations reduce the total flying hours available for a unit's primary training needs. Congressional rules require active fighter units to "fly out" all their allocated training hours for a given fiscal year (FY) before the Air Force can request supplemental funding for contingency hours. This often means that the supplemental hours cannot be requested and approved in time to be flown during the required fiscal year.[1]

Requirements for Adversary Aircraft

Another factor that takes sorties away from the fundamental training regimen and inhibits training opportunities in operational units is the requirement for units to provide their own adversary aircraft for most of their air-superiority training sorties. These are called *red air sorties*, and the participants are expected to emulate recognized enemy tactics and weapon system capabilities as faithfully as possible. This often means the red air pilots cannot fully exploit the advanced tactics, maneuvering envelope, and state-of-the-art cueing systems that the *blue air sorties* in the normal training regimen are designed to build on. Thus, while pilots flying red air sorties do increase their total flying hours, they do not improve their skills as much as if they were flying blue air sorties.

Indeed, according to instructor pilots and supervisors, these sorties can generate negative learning circumstances for pilots in their initial stages of development. For example, after completing initial mission qualification training, many new pilots in units whose training sorties are at a premium discover that their "wingman" status means a scheduling priority so low that the primary way to get on the flying schedule at all is to fly red air sorties. This is likely to continue until the pilots develop their skills enough to upgrade to a higher qualification level. This can take an extended time under any circumstances when

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[1]   This information about supplemental funding rules was provided by AF/XOOT (now AF/A3OT) and ACC/DOT (now ACC/A3T) staff members. We will forego further discussion of these complicated rules to avoid straying too far from our intended topic.

sorties are scarce, but the problem is clearly exacerbated because red air sorties do not contribute as effectively to pilot development as would the same number of flying hours of blue air sorties.

The requirement to devote flying hours to sorties that provide less-effective training provides a simple example of the factors that can degrade the operational training environment. Training effectiveness in operational fighters has indeed varied considerably over time. A look at some of the other factors that generated previous fluctuations will be useful for examining the options that may, or may not, be effective in dealing with the current issues.

Historical Fluctuations in the Effectiveness of the Training Environment

We begin this review with the cessation of hostilities in Southeast Asia. The resulting reduction in operational fighter units, coupled with the lead time required to reduce the production of new aircrew members exiting from an expanded wartime training pipeline, had left the remaining units with excessive numbers of very recently trained (and inexperienced) pilots. Modern aircrew management methods began with the RDTM system, which was introduced to address these problems.

The Role of RDTM

The RDTM system addressed the experience and manning problems by first identifying the absorption problem as the ability for units within a weapon system "to accept new pilots and maintain an acceptable experience level." It provided more-meaningful definitions for *experienced* pilots, established acceptable experience-level criteria for operational units, and provided quantitative methods for managing training pipelines and assignment processes to ensure that future inventories could match projected requirements.[2]

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[2] The Air Force implemented the RDTM system via Program Guidance PG-77-1 (1975); see especially Section C, paragraph 4-10, pp. 4–20). Taylor et al. (2002, p. 40) discusses the system's origin in more detail.

The fundamental RDTM criterion that identifies a fighter pilot as "experienced" is 500 hours in the primary mission aircraft (PMA), and the system's implementing document defines *unit experience levels* as the unit's number of experienced primary mission pilots (aircrew position indicator 1 [API-1]) divided by the total number of API-1 pilots assigned to the unit. The system then used unit experience levels as the primary measure of the unit's ability to continue to sustain itself by developing qualified flight leads, instructor pilots, and supervisors to replace qualified individuals who move on to important staff, management, and command billets commensurate with increasing rank and qualifications.[3] The developmental process clearly includes the experience pilots gain in contexts that may differ substantially from that obtained solely in the pilot's initial 500 hours of flying.

The RDTM implementation also improved the aircrew management process because the steady-state *sustainment rates* (the annual new pilot production rates required to sustain future requirements and maintain unit experience levels) could now be calculated by major weapon system and actual mission design series (MDS). This, in turn, enabled the assignment process to control unit experience levels by matching the flow of new pilots who were completing their initial training with adequate numbers of experienced pilots to ensure that prespecified experience-level criteria were met. This procedure quantified the absorption problem and provided a management approach with which to address it. In this context, the notion of unit experience was identified with unit health in interpreting whether the unit could maintain adequate numbers of assigned pilots who were qualified as flight leads, instructor pilots, and supervisors to conduct its required training and simultaneously distribute sorties relatively equitably to its assigned pilots.[4]

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[3]   A pilot who has previously qualified in another Air Force aircraft is considered experienced in his or her primary fighter aircraft after flying it for 300 hours if their total flying time is at least 1,000 hours. This most commonly occurs with first-assignment instructor pilots, who initially instruct in undergraduate pilot-training programs. Later references to the 500-hour criterion for experienced pilots assume this proviso.

[4]   Taylor et al. (2002) provides a more-complete discussion of absorption issues.

Aircraft Utilization and Training Quantity

Training effectiveness is clearly a function of both the quality and quantity of the available training. With higher manning levels, for example, if the unit's total number of sorties available remains relatively constant, the assigned pilots will average fewer sorties per crew per month (SCM).[5] Low unit experience levels mean that fewer pilots have instructor pilot qualifications, for example, and they will individually need to fly more sorties per month to provide in-flight supervision than are required to maintain their own proficiency. The additional sorties stem from unit training needs driven by upgrades and other supervisory responsibilities. When highly qualified pilots must be tasked to fly more sorties than they require individually, less-qualified pilots will clearly share fewer sorties. As a result, these pilots will have lower SCM averages when sortie resources cannot be increased.[6]

The sortie pool available to fighter units depends primarily on the units' aircraft utilization (UTE) rates. UTE rates, which are a measure of maintenance effectiveness, are defined as the average number of sorties a unit flies per airframe per month. Here, the airframes counted correspond to the unit's primary mission aircraft inventory (PMAI).[7] Following the post–Southeast Asia drawdown, the average number of training sorties available to the new, and thus less experienced, pilots decreased because the number of operational units was decreased abruptly. This was the problem that led to the implementation of the RDTM system. Part of the cause was the overmanning and the low experience and qualification factors that we have already discussed. Low sortie counts and associated flying-hour problems remained, however, even after the RDTM-induced aircrew management improve-

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[5]   Taylor et al. (2002) addresses the quantitative effect of higher manning levels.

[6]   As an exaggerated example, if 20 inexperienced pilots in a unit each need a sortie with an instructor pilot to upgrade to two-ship flight lead and if there is only one instructor pilot in the unit, the instructor pilot will have to fly 20 sorties to provide one sortie to each of the inexperienced pilots.

[7]   Each active fighter squadron currently has either 18 or 24 primary mission aircraft in its inventory (i.e., 18-PMAI or 24-PMAI).

ments had eliminated virtually all the manning and experience issues in the units.[8]

Indeed, even the operational implementation of a sizable aircraft modernization program in the 1970s—which included the addition of the F-15A/C to the fighter force, followed closely by the A-10, the F-16, and the F-15E—did not improve the limited availability of training sorties and flying hours. Nevertheless, the average flying hours per pilot continued to decline for several years. In the face of rapidly increasing airline hiring, experienced fighter pilots voted with their feet and walked over to commercial aviation in significant numbers. However, the Air Force was able to fly itself out of the resulting decline in pilot experience, with an impressive reversal in the flying-hour trend. Along with the new fighters came a steady increase in UTE rates and flying hours. The resulting increase in sortie resources, coupled with the improved aircrew management options the RDTM system brought, enabled an increase in the average fighter pilot's annual flying hours from 150 to 230 between the mid-1970s and the mid-1980s. Furthermore, the more than 50-percent increase in flying hours mainly involved the more-complex areas of the training spectrum.[9]

We have seen that factors such as low UTE rates and sorties that do not contribute to the development or maintenance of flying skills can degrade the training environment, and we have seen that improved aircrew management methods increased UTE rates, which helped overcome the post-Vietnam training problems that developed in operational fighter units.

Additional Training Environment Improvements

Several other training innovations also contributed significantly toward improving the operational training environment. On the eve of the

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[8]   Much of the historical information presented in this and subsequent paragraphs is derived from Anderegg (2001). For additional historical context, see Lambeth (2000).

[9]   Gen William Creech became commander of Tactical Air Command in 1978 and started a gradual recovery from what he termed the "slippery slope" of declining UTE rates and flying hours per pilot. For a complete discussion of how his management style improved the command's flying program, see Peters et al. (1989). The flying increase for fighter pilots is documented in Lambeth (2000, p. 71).

1991 Gulf War, the U.S. Air Force fighter force was strong because several initiatives had come to fruition over the preceding 15 years. Along with the new jets and increased flying hours came new training initiatives—most of which were aimed at the high end of the training spectrum. Although there were many such initiatives, four stand out as the most important: the Red Flag initiative, the aggressor program, the addition of air combat maneuvering and instrumentation (ACMI), and an emphasis on the use of gun cameras and cockpit video recorders.

Red Flag. Analysis of the rate of combat losses compared to the number of airmen in all wars indicated a common thread: If the new pilot survived the first ten missions, he was likely to survive his combat tour. Col Moody Suter, commonly acknowledged as the father of Red Flag, devised a large training exercise, complete with a realistic array of defenses, using the Nellis Air Force Base (AFB), Nevada, training ranges. Beginning in 1977, Red Flag gave young pilots the important first ten missions in peacetime. By the start of the Gulf War, thousands of pilots had been "blooded" at Red Flag in a safe and closely super-vised environment. The success of Red Flag is attributed to four main features:

1. a relatively unconstrained volume of airspace in which pilots could maneuver realistically
2. a functioning, integrated air defense system based on the Soviet model
3. the opportunity to train in large force packages similar to those planned for combat
4. a comprehensive debriefing system that could accurately mea-sure everything from an individual pilot's performance to an assessment of the overall tactical plan.

Aggressors. The *aggressor program* consisted of pilots and fighter aircraft specifically trained and equipped to replicate the Soviets and the Soviet system and to oppose the pilots in operational units. It was the beginning of a culture of learning to fight dissimilar aircraft that use dissimilar tactics. The aggressors not only provided adversary sup-

port for Red Flag but also conducted regular and frequent "road shows" at fighter bases to train pilots in smaller scenarios.

Air Combat Maneuvering and Instrumentation. The *ACMI system* employs a missile-sized pod on the fighter and a linked group of receiving stations and computers on the ground that capture every move a fighter makes in a dogfight. The data can then be replayed after the fight as a visual presentation that shows all the fighters who shot whom, when, where, and how. These replays accelerated the learning process dramatically, and soon the system spread from Nellis to several other sites around the world. Before ACMI, the victor in an air-to-air fight was often the pilot who could talk the fastest or wave his hands the most, and kills were claimed based on each pilot's own interpretation of how well employment parameters were met. After an ACMI-telemetered engagement, however, the results were irrefutable. Pilots could see clearly during the debrief what worked and what did not.

Gun Cameras and Cockpit Video Recorder. Several models of the primary fighter-bomber of the Vietnam War, the F-4, had no gun camera. Part of the training culture that evolved along with Red Flag, aggressors, and ACMI was the return of the gun camera, followed rapidly by several iterations of video recorders to capture the parameters of a bombing pass or a simulated air-to-air missile firing. Similar to ACMI results, the gun camera showed the pilot his precise position and parameters at simulated or actual weapon release.

Summary. Red Flag, the aggressor program, ACMI, gun cameras, and video recorders all combined with the increasing availability of flying hours for training to improve both the quality and quantity of training and dramatically improved the operational training environment that was available at the start of the Gulf War. The superior performance of the Air Force's fighter force in that war speaks to the quality of the prewar training program for the participating pilots. Since the Gulf War, however, the Air Force has had less "quantity" training, as seen in the decline of sorties available for training.

Post–Gulf War Training Environment

The data in Figure 2.2 show the decreases, since the Gulf War, in UTE rates, SCM, hours per crew per month, and the portion of UTE allo-

Figure 2.2
Air Combat Command F-15A/C UTE, Hours, Sorties Comparison
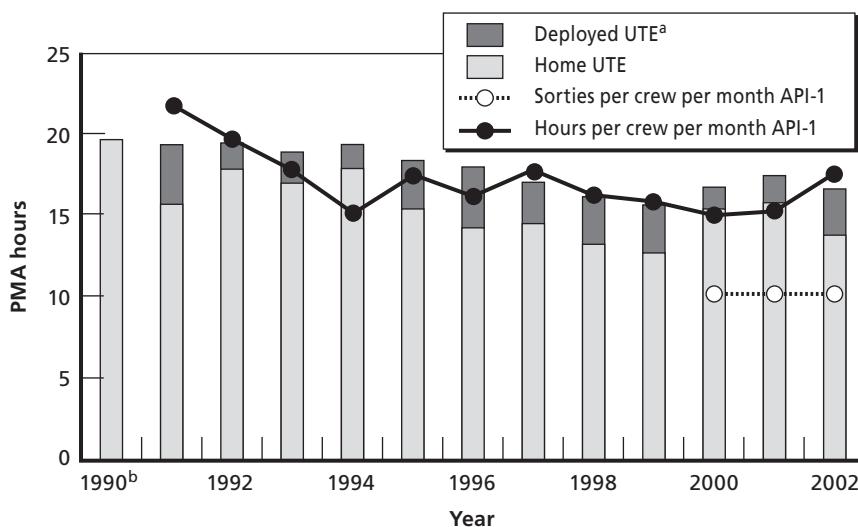
^{a} Includes Keflavik, Iceland, and Operations Northern Watch and Southern Watch.
^{b} Pre-AEF and Keflavik.

RAND *MG597-2.2*

cated to home-station training for Air Combat Command's (ACC's) F-15Cs.[10]

The UTE rate is further broken down into deployed UTE and home UTE.[11] It is important to note that the deployed UTE rate probably represents disproportionately more hours than does the home UTE because many contingency sorties were flown as combat air patrol or package support sorties that averaged four to six hours each, while normal training sorties are programmed at only 1.3 hours each. Figure 2.2 shows that in 1990, the year before the Gulf War, all the sorties, and thus all the available flying hours, were devoted to normal operational training. During the period following the

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[10] Data provided by ACC/DOT, 2003.

[11] The deployed UTE includes contingency missions flown as part of Operation Noble Eagle, even if they were flown from the unit's home station, but it does not include sorties flown during specified training deployments, such as Red Flag.

Gulf War, however, the overall drop in aircraft utilization, coupled with the cost of the sorties devoted to contingency operations, reduced the average number of sorties (per airframe per month) that could be devoted to operational training by some 30 percent. We may presume that the monthly flying hours devoted to normal training per inexperienced pilot decreased by at least that amount. Similar data for the other fighter MDSs reveal similar trends, although the training value of the contingency support flown after the onset of open hostilities in Afghanistan and Iraq could perhaps be argued to have been more valuable for these MDSs than for the F-15Cs.[12]

Experience and Qualifications
RDTM included the implicit assumption that, if enough pilots could be absorbed, these pilots could continue their operational development apace and unimpeded during subsequent operational tours of duty. The terminology that identifies a unit's experience level with the adequacy of its assigned qualified pilots was completely valid when it was originally made because the continued development of fighter pilots was virtually assured by subsequent operational assignments.[13] Moreover, the identification of experience was further recognized in the Ready Aircrew Program, which specifies operational training requirements in fighter units. Except for brief periods in which the assignment system was required to react abruptly to significant policy changes, it remained valid for over two decades.

However, recent RAND analysis has raised strong concerns about whether the assumption that aircrews can continue their operational development once they meet their weapon system's experience defini-

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[12] As discussed previously, contingency sorties do provide limited amounts of training initially, but the value of the training degrades rapidly with continued repetition. Participating pilots have typically considered the training available from contingency operations for the A/OA-10 to be somewhat more valuable than that available for the other fighters throughout the period depicted. See Stillion (1999) for a more-comprehensive treatment of aircrew training issues during contingency operations in the 1990s.

[13] This identification was also fully incorporated in the aircrew management analysis of Taylor et al. (2002), which addresses the distinctions between unit training needs and individual training summations.

tion is still valid.[14] As an example, discussions with unit instructor pilots and supervisors have confirmed that there is a vast difference between pilots who have recently met the experience criterion and pilots who are ready to move into staff or supervisory billets. Pilots in the latter group require a great deal more experience than the 500-hour criterion represents, and indeed the binary (yes-or-no) definition of experience will no longer be useful if this continued development of additional qualifications is no longer assured. The opportunity for these pilots to continue their development after meeting the initial 500-hour definition so that they can achieve the additional qualifications required for moving on to new roles and assignments is the subject of ongoing RAND research.[15]

What Does This Mean?

Both the quality and quantity of the training available in operational units has changed considerably in the three decades since the 500-hour criterion was established as part of the RDTM system. The operational training environment improved dramatically in the late 1970s and 1980s as the Air Force increased aircraft utilization rates, modernized its fighter force, and implemented a number of training innovations that definitely enhanced the opportunities for pilots to train in the operational units. Following the first Gulf War, however, the training environment began to deteriorate as overall UTE rates gradually decreased and a significant portion of the hours inexperienced pilots flew had to be devoted to low-value contingency operations. The mag-

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[14] Taylor (2006).

[15] Taylor, Moore, and Roll (2000) and Bigelow et al. (2003) document the operational training needs for fighter units. As previously referenced, the absorption issues are documented in Taylor et al. (2002). The most obvious example of an abrupt policy change that generated a system reaction is the fall of the Berlin Wall and the dramatic drawdown in personnel and force structure that ensued. The interview and survey data will be discussed in more detail later in this report. Finally, a related project examining issues associated with developing rated officers to meet authorized billet requirements has also identified much more-formal qualifications for most staff officers and supervisor billet authorizations than the 500-hour definition.

nitude of the contingency effort is clear from the fact that, during the 10 years immediately following the Gulf War, the Air Force expended nearly 400,000 sorties simply to maintain no-fly zones in northern and southern Iraq. The training environment was further degraded by the fact that the active fighter force structure was cut in half during almost the same period, while the number of fighter pilot positions decreased by only 23 percent, effectively increasing the ratio of pilots to aircraft.[16]

The downward trend in overall UTE rates stabilized in 2001 as the Air Force reinstated standardized UTE rates for all combat air forces aircraft and the contingency commitment has been slightly mitigated after a full cycle of programmed contingency support under the air expeditionary force (AEF) structure. However, the fact remains that, even if all available UTE were expended on home training, the number of sorties (and, thus, flying hours) flown per unit for training would still be significantly lower than it was before the 1991 Gulf War.

The primary reductions in available training are at the higher and more-complex end of the training spectrum depicted in Figure 2.1. This is because safety of flight and supervisory concerns will always demand suspending the more-complex training activities as pilots begin to lose proficiency in the fundamental skills required to accomplish the high-end training. This, coupled with the fact that flight leads and instructor pilots must tailor training scenarios to accommodate the least proficient flight members, means that the more-difficult training scenarios become much harder to schedule as the available training sorties decrease. Thus, the overall training quality will generally drop as the quantity of training available decreases. The total flying hours available to a unit is directly proportional to the unit's average UTE rate. In today's environment, the combat air forces's standard UTE rates (essentially the highest rates logistics community can achieve given

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[16] The sortie count is from a briefing given by then–Lt Gen T. Michael Moseley to the CENTAF Lessons Learned Conference, Nellis AFB, Nevada, July 18, 2003. The fighter force structure numbers, which are plotted in Figure 6.1 in Taylor et al. (2002, p. 98), originally came from the Air Staff (AF/XPPE). In FY 1994, there were 14,426 officers in 11XX duty-coded positions (fighter pilot). In FY 2001, this number was 11,178, for a reduction of approximately 23 percent.

parts funding, manning levels, and maintenance experience levels) and the flying-hour funding reductions that have been mandated to ease budgetary disconnects combine to limit any appreciable increases in available flying hours.

Chapter Three will examine the potential for improving the available training, without increasing the hours flown, by using advanced high-fidelity simulation facilities. However, we will first examine the causes and consequences of the continuing pressure to increase manning levels and decrease experience levels in operational fighter units.

The Production of New Pilots and Overmanning Issues

During the post–Cold War drawdown and after the end of the first Gulf War, pilot training was cut radically rather than being kept at inventory sustainment levels. Total undergraduate pilot training cohorts were reduced to less than half of their required sustainment levels, and new fighter pilot cohorts were reduced even more aggressively, with many assignments into fighters requiring a three-year nonflying period as a member of a "pilot bank" before formal training in fighters could begin. These low pilot-production rates were implemented in FY 1992 and continued into FY 1996, creating the "pilot bathtub" (shortages in pilot inventories relative to the annual cohorts that production at sustainment levels would have provided) that has plagued aircrew managers for over a decade.

An attempt to remedy the situation was made at a four-star–rated summit convened by the Air Force Chief of Staff in 1996, which set production goals for new fighter pilots at 370 pilots per year beginning in FY 1997. This objective could not be met and was eventually reduced to 330 at a subsequent summit in 1999. This goal has also never been met because of pipeline production constraints, and the number of experienced fighter pilots has continued to suffer as result.

The efforts to meet these goals, however, have generated problems with overmanning and low experience levels in a number of units because the flow of new pilots exceeded the absorption capacity of the available active fighter force structure. The most egregious problems

occurred in the A/OA-10 unit at Pope AFB, North Carolina, in FY 2000, but F-15C units have also been severely stressed throughout the 2000s. When units are overmanned with newly trained fighter pilots, the average SCM for the assigned pilots must decrease if the sortie resources remain constant. This means that inexperienced pilots will fly even less because additional instructor pilot sorties would be required to train the excess flow of incoming pilots.[17]

The absorption analysis in Taylor et al. (2002) carefully examined these issues, but the dynamic effect of the ongoing reduction in overall active fighter force structure raises additional concerns. If current Air Force leadership is sufficiently intent on not repeating the mistakes made following the end of the first Gulf War, it may not recognize the damage to the operational training environment that will result if existing production goals are not reduced to match the force structure reductions. It is becoming very clear that the Air Force will not be able to fly its way out of the impending crisis unless it can use more airframes to absorb new pilots and/or find a way to significantly increase the UTE rates flown by the existing airframes. Indeed, if excessive numbers of new pilots are sent to fly a continually decreasing number of operational aircraft, those who leave the weapon system at the end of an initial tour will have less of an opportunity to return to their primary aircraft following an intervening tour. Those who cannot continue to develop their operational skills during a second flying tour in their primary aircraft will never be able to acquire the knowledge or skills that are required to fill the staff and operations center billets that are driving the high production quotas. This, of course, would completely defeat the primary purpose of training higher numbers of new pilots in the first place.[18]

Our historical discussion of the training environment has confirmed that fluctuations in training effectiveness are not a new phe-

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[17] Chapter Two in Taylor et al. (2002) discusses the so-called "Pope syndrome" training issues.

[18] Taylor et al. (2002) documents the steady-state absorption results. The dynamic issues specific to the F-15C were briefed to the Aircrew Review 2005 attendees on December 12, 2005. The latter results will be fully documented at a later date.

nomenon for operational fighter units. The Air Force has coped with training degradations successfully in the past by developing new processes and, when necessary, new resources, systems, or procedures to improve aircrew training and management methods. The issue that is new, however, and the one that will make the Air Force reexamine and refine its methods, is the "decoupling" of the absorption and development processes for pilots: Absorption of a pilot no longer ensures that further development will be possible. The development process that enables a pilot to become credentialed as a flight lead or instructor pilot often occurs during a second tour in his or her primary aircraft. Historically, the system has remained sufficiently balanced to ensure that these second tours were always available, even if they occurred after an intervening assignment. Thus, once a pilot was absorbed, his or her development process was never limited by the lack of availability of a second tour. Ongoing RAND work indicates, however, that certain policy options could drive the system far enough out of balance to severely limit opportunities for second tours and continued aircrew development (Taylor, 2006).

Both the quality improvements after the conflict in Southeast Asia that new technology (ACMI, cockpit video recorders) enabled and the quantity improvements that new aircraft and better maintenance enabled contributed to the development of an outstanding Air Force fighter capability. Now that the available *quantity* of training is declining, an important question is whether or not improvements in training quality can make up, at least in part, for the decline. High-fidelity simulation systems with MTC facilities have the potential to contribute positively to the training process, but it is important to recognize that they will not resolve the training crisis that will result from the excessive flows of new pilots into the operational units unless these pilots will have adequate opportunities to continue the development of essential qualifications in subsequent operational assignments. Further, it is important to understand whether pilots consider the types of experience available from MTC facilities to be equivalent to those in the aircraft. It is also important to understand whether current RDTM measures of experience are still valid, both for unit measures of effectiveness and for an individual pilot's readiness for varying positions of

responsibility. If the experience assumption that was fundamental to the development of the RDTM system is no longer valid, other measures need to be examined, because aircrew managers will require new methods for identifying and tracking the continuing developmental options available to pilots after their initial operational flying opportunities.[19] We address these issues in the next two chapters.

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[19] The Air Force has recently implemented an officer development system that requires officers to receive periodic review and feedback from an appropriate development team that includes senior-level members. The problem at this point for rated officers, however, is that these reviews typically begin as officers become eligible for promotion to the grade of major. This currently occurs after they normally would have completed a second operational assignment.

High-Fidelity Simulators with Mission Training Centers

High-fidelity simulation systems coupled with MTCs incorporate state-of-the-art electronic components, including high-resolution visual graphics and compellingly realistic cockpit components.[1] In air-superiority units, the actual cockpits are located in the MTCs, which also incorporate advanced briefing and debriefing facilities and ACMI-like mission histories that enable pilots to construct and visually deconstruct all the engagements accomplished during a mission and to use recreated cockpit displays and depictions of relative aircraft positions to thoroughly evaluate kill criteria, weapon effectiveness, and individual pilot maneuvering proficiencies and tactical expertise. These systems also incorporate distributed networks that enable aircrews to include a variety of potential threat environments and constructive (computer-generated and fully automated) assets and adversaries that can be designated as either red force or blue force resources.[2] These networks will also enable other operational units, as well as appropriately equipped and networked command-and-control resources, such as air operations centers, to participate simultaneously in employment and other simula-

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[1] This brief chapter cannot address many important simulator-related issues. A useful resource is Lee (2005), which includes chapters on visual scene simulation, sound effects and communications simulation, flight simulators in pilot training and evaluation, and limitations in flight simulator design and use.

[2] It is useful to distinguish between *constructive* resources, which are computer generated and also respond and react during the session in accordance with their programmed software, and *virtual* resources, which incorporate a person in the loop to control his or her responses and reactions.

tion exercises. These networks can also incorporate input data from the computer systems aboard appropriately linked live resources, as well as simulators and other linked facilities. The ability to combine constructive, virtual, and live resources simultaneously in these training missions has led them to be called *distributed mission operations* (DMO). Since the Air Force pioneered the development of these systems, many Air Force leaders have referred to the simulator systems themselves as *DMO systems*. In this monograph, we will conform to the terminology the Air Force currently prefers and refer to them as *high-fidelity* or *DMO-capable simulator systems* because the full DMO capability will not be realized until the facilities have been fully funded and a number of additional weapon systems have been linked into the distributed network.[3]

Earlier simulation training systems focused on training skills in instruments and navigation and on skills such as procedural knowledge and "switchology" issues that apply at the lower end of the building-block model (Figure 2.1). The advanced simulator systems, however, also make it possible to provide simulator training in skills required in the higher levels of the training spectrum, such as ACT and LFE sorties. Thus, these new resources make it possible to develop the kinds of skills that previously required the participation of multiple live aircraft and often a great deal of external coordination, cost, and effort to conduct.[4]

Air Force leadership regarded the development of these advanced simulator systems as a fundamental component of a training transformation. Indeed, in their Senate testimony supporting the FY 2006

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[3] Regarding the planned scope of the DMO system, Walker (2004) wrote,

> The Air Force has a DMO network that includes four aircraft platforms—the F-15C, F-16, E-3 Airborne Warning and Control System (AWACS), and the E-8C Joint Surveillance Targeting Attack Radar System (JSTARS). New platforms are slated for DMO participation, including the F-15E, R-135 Rivet Joint reconnaissance aircraft, B-1 and B-2 bombers and the A-10 ground attack aircraft. The F/A-22 simulators at Tyndall Air Force Base, Fla., also are under contract to become DMO-compatible.

[4] For the most recent review of flying simulation research specifically related to combat training, see Bell and Waag (1998).

budget, the acting Secretary of the Air Force and the then–Air Force Chief of Staff stated the following (Jumper, 2005, pp. 21–22):

> Distributed Mission Operations (DMO) is the cornerstone for Air Force training transformation. It is a readiness initiative to train warfighters as they expect to fight using simulation and high-fidelity architecture to link training at dispersed locations. DMO will reduce travel costs and operations tempo while providing mission rehearsal in an operationally realistic environment to maintain combat readiness and provide support to operations. It will prepare and assess Air and Space Expeditionary Forces and prepare AOC [air operations center] weapon systems, including Joint Force Air Component Commanders, for real-world missions. As an integration effort, DMO will leverage existing and emerging programs and technologies to fill gaps in total team training, rehearsal, and operations support.

The systems are designed to support all stages of flight training, including initial qualification, mission qualification, continuation, and flight lead and instructor pilot upgrade training. However, MTC cockpits in fighter units do not include motion simulation because the technology cannot replicate the high g-forces that pilots experience in modern fighters.[5] They do have advantages that are not available in the aircraft, however. Earlier, we noted four characteristics of Red Flag that were important to its success:

1. a relatively unconstrained volume of airspace in which pilots could maneuver realistically
2. a functioning integrated air defense system based on the Soviet model
3. the opportunity to train in large force packages similar to those planned for combat

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[5] One of our reviewers noted that research at Armstrong Laboratories also found that a full-fidelity cockpit and some visual cues were more important than making an effort to include motion.

4. a comprehensive debriefing system that could accurately measure everything from an individual pilot's performance to an assessment of the overall tactical plan.

Each of these elements is present to some degree in the high-fidelity simulators. It is also interesting to note that Desert Pivot, a virtual flag exercise using linked DMO resources, was initiated in October 2000 at Kirtland AFB, New Mexico.

The Potential Benefits of DMO-Capable Systems

Pilots indicate that a training mission in an MTC cockpit is not identical to flying a training sortie in the aircraft but that the fidelity of the training is far greater than they have ever experienced in older simulator systems. The MTC also provides cockpits that can be used more efficiently for training than can actual aircraft cockpits. For example, MTC training is not as susceptible as aircraft sorties are to cancellations or significant modifications to the original mission plan because of weather or mechanical problems. In addition, MTC missions do not involve extensive ground operations, departure procedures, transit to and from the range or military operating area, and air traffic control issues and do not require recovery, approach, or arrival procedures.[6] Furthermore, the ability to quickly reset the simulator to refly an engagement or initiate a new phase of the training profile multiplies the quantity of training that can be accomplished per unit time in the MTC relative to that of a similar training profile flown as a live flight. A live mission would need to rejoin or reform the aircraft in flight, send them to specified starting positions, and set things up again from scratch to refly an intercept or engagement. One estimate is that the MTC may increase the quantity of training accomplished per unit of time in the cockpit by a 4:1 ratio over the quantity available on a live mission (BGI, 2002). The ACMI-like capability to replay sorties from recorded data also makes mission reconstructions and

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[6] Each of these processes can, however, be accomplished in the MTC when such training is required.

debriefings more efficient. Less time is spent discussing *whether* something happened, so more time can be devoted to discussing *how* and *why* things happened and how improvements could be made in flying similar missions in the future.

MTC cockpits can be regarded as additional training resources for an operational unit. Scheduling this training effectively requires a degree of effort similar to that for live sorties, and the training missions consume equivalent amounts of personnel resources and time. This means that pilots scheduled for MTC training are not available for live training during the preparation, execution, and reconstruction phases of the MTC training. The converse, of course, is also true, inasmuch as pilots scheduled for live training are likewise unavailable for MTC training for extended periods during the training day. Upgrading pilots and those with little experience require exactly the same amount of supervision from flight leads and instructor pilots on MTC missions as they would require on a live sortie with a similar training profile. Therefore, high-fidelity simulators do not create additional training time in a pilot's day, even though they can make it possible to use the time more efficiently. These simulators do provide extremely useful training resources that can be coordinated with pilots' live training schedules and significantly enhance their development of additional skills and qualifications.

The new simulator systems can also provide training to cope with emergency circumstances, such as battle damage, major system failures, and other serious emergencies, that cannot be practiced realistically during live training in an aircraft. As one of many examples of the value of simulator training to cope with actual in-flight emergency situations, Boeing reports that a pilot discussing how he landed a C-17 after his number two engine exploded at takeoff from Baghdad (after taking a hit from enemy ground fire) indicated that his crew had practiced the required procedures many times in the simulator and stated, "It was nothing different because I was so used to the simulator." C-17

units have Federal Aviation Administration Category C+ simulator systems, which provide as high a fidelity level as any Air Force system.[7]

MTCs also provide opportunities for types of training profiles that are extremely difficult and costly to accomplish in a live-fly mode because of the large numbers of weapon systems and other resources that are required. A striking example of these options is the opportunity to conduct LFE exercises. Exercise planners must invest extensive effort and funds to task and assemble a realistic composition of disparate units with appropriate mission tasking and Designed Operational Capability (DOC) statements to organize and execute a live-fly LFE.[8] Also, the participating units typically must devote the bulk of their training resources to preparing for and participating in the exercise, thereby preventing upgrade and other daily training operations for a fixed period. LFE training in an MTC is much simpler and less expensive. MTCs provide a nearly unlimited supply of credible and constructive red air support (an MTC can manage approximately 200 entities at a time in a scenario), and the mechanical problems that would jeopardize an aircraft exercise of this magnitude are far less likely with MTCs. Finally, the MTC provides unlimited constructive air and weapon-release space for the exercise. DMO offers the potential of being a powerful partner of, or extension to, higher-end training, such as traditional Red Flag, or LFE exercises.[9]

These advanced simulator systems, on the other hand, can also complement and fully support more-basic flying training needs. For example, the MTC can be used to practice a training profile prior to flying the same profile in an aircraft, reducing the probability of losing the training effectiveness of the live sortie due to aircrew mistakes or planning errors, thereby increasing the efficiency of the available air-

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[7] See Larock (2005b). See also Larock (2005a) for additional information on DMO capabilities in the F-15C and other aircraft.

[8] DOC statements "provide a narrative description of the unit's wartime mission(s)." See AFI 10-201 (2006, para. 1.7).

[9] Maj Gen Teresa Marné Peterson, the former Air Staff Director of Operations and Training (AF/A3O), said that DMO exercises are available "at a fraction of the cost of getting everyone together at the same range" (quoted in Hebert, 2004, p. 41).

craft training time. When live-fly sortie resources are in short supply, as has been the case—especially for inexperienced wingmen—in F-15C units since FY 2000, training schedules can be coordinated so that the limited number of live sorties can be used more efficiently. For example, Bennett and Crane (2002) reported that spin-up training using MTC reduced noneffective sorties at USAF Weapons School by 12 percent.[10] We will return to this notion later because we feel that it requires additional analysis to exploit the opportunities fully.

Units can also rehearse missions in specific theaters where they may expect to be tasked to conduct combat operations. This means that they can fly against constructive, integrated air-defense systems that are essentially identical (within available intelligence estimates and computer programming limitations) to those they will encounter in wartime mission tasking. Force package size and the types of participation are nearly unlimited, and this is valuable on the higher end of the training spectrum because it enables crews to practice the complex integration and communication issues of operating in a large, diverse package of combat aircraft in constant communication with combat operations centers.[11] Indeed, following the first night of combat operations in Operation Iraqi Freedom, a highly experienced F-16 defense suppression instructor pilot and Weapons School graduate made the following statement:

> I was *downtown* at the start of tonight's activities and got to launch the first HARM [High-Speed Antiradiation Missile] of Operation Iraqi Freedom. . . . the location of my flight and the tactics

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[10] See also Crane, Robbins, and Bennett (2000). *Spin-up training* refers to training conducted to prepare pilots for deployment in a specific theater.

[11] Without exception, the pilots we interviewed acknowledged the usefulness of simulator training and universally praised the advanced simulators with MTC capability—especially in comparison to the previous generation of simulators. Many, however, would immediately follow positive comments with concerns and issues comparing simulator training to live training. These concerns dealt primarily with the "airmanship skills" that are discussed in the next section.

employed were EXACTLY like we were practicing in the F-16 MTC at Shaw before we left. . . . talk about *Mission Rehearsal*![12]

Shortcomings of Simulator Systems

Inherent Lack of Fidelity

Even the most advanced of modern simulators has an inherent lack of fidelity. Very knowledgeable engineers and pilots who met with our research team members stressed this fact during site visits to simulator research and development centers.[13] The most obvious reaction that is difficult to simulate is the psychological stress that can be caused by anticipation of the catastrophic consequences of serious in-flight errors or lapses in judgment. We heard from several sources that pilots always realize that they will walk away from their simulator cockpit because no one has ever died from errors made during simulator training. The same sense of security is rarely present in flight, especially during combat operations. These sources do confirm that realistic simulator training can certainly enhance one's ability to cope with and overcome many of these anxieties. Certain issues, however, such as the stark realities of the catastrophic loss of a flight member in an explosion or crash, cannot be simulated very effectively.[14]

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[12] The quote is taken from a briefing by the ACC/DO (now ACC/A3) to the 2003 Combat and Mobility Air Forces Commanders' Conference, Nellis AFB, October 2003; capitalization and emphasis are as in the original. HARM is the primary munition against many enemy air defense systems. It should also be noted that the Iraqi air defense system, which remained essentially intact at the beginning of Iraqi Freedom, was the primary target during the first night's operations. "Downtown" refers, of course, to downtown Baghdad, where the Iraqi air defenses were concentrated and should have been the most effective.

[13] The sites visited included the Integrated Defense Systems Division of the Boeing Company, St. Louis, Missouri; the NASA Ames Research Center, Moffett Field, California; and AFRL's Warfighter Readiness Research Division, Mesa, Arizona.

[14] One reviewer notes that, in the current environment, simulator training sometimes has better "fidelity" to wartime training than do live sorties. Since F-15s and F-16s flying peacetime missions were configured differently from wartime missions, researchers at Armstrong Laboratories found that "negative" training was occurring in the air that could be overcome with early design of simulators with a full-fidelity cockpit.

Another well-known limitation in simulator fidelity affects the skills required to visually acquire and identify airborne targets and ground references. The computer graphics and visual display systems associated with simulator systems are continually improving, but they still lack lifelike resolution. These visual limitations result primarily from technical limitations in the size and number of pixels that can be generated and displayed within the optical systems, but they also relate to the requirement to display the visual features on two-dimensional screens within the MTC cockpit. This lack of three-dimensional cues is especially notable during high-speed operations at very low altitudes (e.g., within 300 feet of the ground). These operations are much less important for air-superiority units and have become less so for multi-role fighter units employing standoff weapons, but they could become critical once again for these units as tactics evolve.

The final limitation in simulator fidelity for fighter units is the inability to replicate the g-forces exerted on the pilots during normal fighter operations. These forces can reach 9 g, which means that objects in the cockpit, including the internal organs and other body parts of the pilot, are subjected to nine times the forces normally exerted in straight and level flight. It can be exhausting to maintain the blood supply to the pilot's brain and eyes, neither of which will function properly when the oxygen supply carried in the blood is interrupted.

Airmanship
Knowledgeable pilots and simulator experts categorize many of the pilot skills affected by the fidelity limitations as airmanship skills. Many of the same experts agree that improving airmanship skills is one of the most important elements of developing overall pilot skills, increasing pilots' qualifications and preparing them for greater responsibilities. The implication may be that more highly qualified pilots can maintain their skills more reliably using advanced simulator training than could newer, less-experienced pilots whose airmanship skills are not yet as highly developed. This concept deserves more careful examination.

The Air Force has long believed that the flying skills of less-experienced pilots are more perishable because maintaining these skills consistently requires more training and practice for them than for more

experienced pilots. Indeed, the Ready Aircrew Program tasking messages for all fighters require fewer sorties per training cycle for pilots who meet the 500-hour experience definition than for those who do not. The training models we developed for operational units in our earlier work partially confirmed this point, but it also appeared to us that pilots who had recently qualified for additional responsibilities, such as new flight leads, needed almost as much training per unit time to maintain and develop the new skills required to lead flights as did the inexperienced wingmen. Similar training needs also apply to new instructor pilots. This means that most pilots who actually require less training are the experienced instructor pilots. These pilots would have to be considered highly experienced pilots in any meaningful distribution of experience based on pilot qualifications and the skills required to perform the corresponding duties.[15]

To relate these issues to simulator training in advanced facilities, it will be instructive to look at the training policies of the major airlines. It is worth noting that the major airlines never use aircraft equipment solely to provide live training for their pilots. The very first live flight a newly hired pilot makes will be a regularly scheduled flight carrying revenue passengers or cargo. All the initial training required to prepare a new pilot for a first flight takes place in high-fidelity simulators. Indeed, all the upgrade training required for airline pilots to change crew positions or transition to new types of equipment is also conducted in high-fidelity simulators. Several features of this training contribute to the airlines' ability to avoid the costs that would result from using aircraft solely for crew training, but the primary factor that distinguishes airline and Air Force training needs is the experience levels of the new pilots. We visited several major airlines in the late 1990s, when they were still aggressively hiring new pilots, and discovered that they were hiring former military pilots with at least 1,500 to 3,000 flying hours, depending on the military weapon system a pilot had flown, or civilian pilots with at least 4,500 flying hours. Simulator

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[15] It is perhaps ironic that the highly experienced instructor pilots, who require less training per month to maintain their own flying skills, are precisely the ones who will fly more sorties per month in a unit overmanned with new pilots, to supervise their upgrade requirements.

hours were neither counted nor credited in the hiring process. It should be noted that these new hires are very highly experienced relative to the operational fighter world in the Air Force. Pilots with this much flying experience would be unlikely to require much training in the basic airmanship skills that simulators may not be able to provide adequately. Indeed, to meet the commercial 1,500-hour minimum for hiring military fighter pilots, they would have to complete at least three typical flying assignments in their primary aircraft. In an operational fighter wing, pilots with that level of background and experience would be available only for very senior supervisory and command positions.[16]

At the other end of the qualification hierarchy, additional RAND research confirmed that airmanship issues were precisely the reason the Air Education and Training Command has resisted replacing live sorties with simulator training in the formal training unit programs that initially qualify new fighter pilots. The airmanship factors were identified as follows: "Pulling g's, the fear of death from making a mistake, heat, radio traffic, and equipment failures were all described as difficult or impossible to simulate" (Ausink et al., 2005, p. 64).

We introduce this information because it supports the assertion that highly experienced pilots, whose basic airmanship skills are fully developed, have the potential to rely more heavily on appropriate simulator training to maintain or develop primary flying skills than those with little experience, who must continually strive to develop their airmanship and other skills. A related concept, raised by the experts at Boeing, is that the live sorties that are available should be carefully managed, especially when they are in short supply, to ensure that newly assigned pilots continue to develop all skills required, including those that are less effectively inculcated by advanced simulators. This requires the units to use appropriately coordinated and balanced live and simulator training programs.

The Air Force Research Laboratory (AFRL) and ACC have sponsored a considerable body of research addressing these issues. Their

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[16] The visits to major airlines supported our research on the effect of airline hiring on Air Force pilot retention, which is documented in Taylor, Moore, and Roll (2000). The airlines visited included American, Delta, and Southwest.

studies address the mission-essential competencies required for tactical flying and the relationship between the operational training environment and the combat circumstances within which the pilots are training to employ their tactical flying skills. This research provides a foundation on which to base training directives that incorporate a more-efficient mix of live and simulator training. (See Colegrove, 2005, and Colegrove and Bennett, 2005.)

The Role of DMO-Capable Simulators in Operational Fighter Units

Our interviews and discussions with simulator experts as well as our visits with operational supervisors, instructor pilots, and our subsequent discussions with concerned staff officers all confirm that there is a great deal of value in the training that pilots receive in high-fidelity simulator systems.[17] Indeed, there was universal acceptance of the fact that, if the simulator training could be scheduled to complement and support an appropriate live training schedule, the live training that is available could be quite a bit more effective in developing and maintaining required skills than would a similar amount of live training that was not augmented with the simulator training. This raises a related question about how (or whether) the extra training that can be accomplished per flying hour should be credited to the pilots.

Our analysis has led us to the conclusion that DMO-capable simulator training should indeed be credited to the pilots in an appropriate manner and that this training should be included in training requirements so that unit supervisors can thoroughly track and evaluate the training, rather than rely solely on an undocumented system consisting of subjective judgments. This is the only option we see that can ensure the coordination and integration of the live training the pilots receive with the available simulator training. This process should support an

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[17] The staff offices visited included the operations and training shops at the Air Staff (AF/A3OT), Air Combat Command Operations and Training (ACC/A3T), and Air Mobility Command Operations and Training (AMC/A3T).

ongoing effort to improve the overall training quality available in the operational units.

Our preliminary dynamic estimates indicate that current programmed pilot-production levels, coupled with the programmed reductions in the F-15C force structure (and consequently in the numbers of units), will mean that at least 80 percent of the API-1 billet authorizations in these units by FY 2011 will be filled with first-tour pilots. This would preclude the continued development of most of these pilots during a second tour in their primary aircraft, and our final chapter will address the fact that these tours will remain absolutely essential for pilots to develop into qualified supervisors and staff officers.[18]

The potential benefits of greater use of high-fidelity simulator systems thus outweigh well-known limitations of training in these systems. The Air Force should therefore formalize methods of counting the time in these systems to help measure experience.

Additional Concerns and Caveats

Funding

The advanced simulator facilities have funding issues. Currently, no operational fighter, including the F-15C, is fully supported by DMO-capable simulator systems. The F-15C is indeed the most robust system, but one squadron has no advanced simulator facilities, and another has only a two-cockpit MTC.[19] The Block 50 version of the F-16C is currently the only other fighter with an advanced simulator capability, and the remaining F-16Cs, as well as the F-15Es and A/OA-10s, all have simulator funding issues that need to be resolved. Even projected F-22A units have simulator funding issues. For the concept of coordinated and

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[18] This problem is dynamic, so it is difficult to quantify accurately. It should, however, be easy to see that continuing force-structure reductions during the nominal four years after a pilot's first tour in a given aircraft type will mean that even fewer of the aircraft will be available, making it more difficult for that pilot to return for a second tour. We should also emphasize that the 80-percent-fill factor could be considerably lower than the actual value.

[19] When air-superiority tactics are based on a fundamental four-ship employment unit, two-ship training can be far from adequate.

integrated training programs to be efficient, all units must have essentially identical simulator systems that are fully functional throughout the fleet, or such systems must be readily available to all units.

An additional funding issue that affects simulator effectiveness is the requirement to ensure that the software programs in the simulator remain consistent with those in the aircraft. The Air Force had to remove the previous-generation F-16C simulators from operational units in the 1990s because funding issues precluded keeping that system's operational flight program software aligned with changes that were being made in the aircraft's software. Simulators with outdated software can easily result in negative training, especially for new pilots.

The final funding issues are current and projected reductions in flying-hour funding. A reduction in F-15C flying hours was required to free funding for additional DMO-capable systems for other MDSs. Subsequent flying-hour cuts will be required for the Air Force to resolve ongoing budgetary disconnects in the FY 2008 Program Objective Memorandum because options for reducing discretionary spending are extremely limited. Some of these reductions may be offset by contingency flying hours, but the availability and training value of these will need to be carefully examined as the Air Force develops its integrated training programs.[20]

Scheduling and Supervision

Our final concerns deal with the scheduling and supervision of simulator training. As previously discussed, for most training profiles, inexperienced pilots and those with lower qualification levels require the same level of supervision in the MTC as they do in the aircraft. When flight leads and instructor pilots are in high demand and short supply in a unit, they will supervise far more training than they individually require. The advanced simulators are operated under contract at all Air Force units, but policies on whether contractor personnel can provide the required training supervision, by acting as instructor pilots or flight leads in the MTCs, differ by location. These policies need to be evaluated and standardized if the Air Force is going to build fully

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[20] Erwin (2000) also discusses the issues associated with outdated software in simulators.

effective integrated live and simulator training programs. If the objective of consistent, effective training across all the operational units is to be achieved, overall training effectiveness cannot be allowed to vary significantly from one location to another.

Our concerns embrace both ends of the policy spectrum on this issue. If contractor personnel are going to supervise actual training, the Air Force needs to ensure that their supervision skills meet acceptable quality standards and must also evaluate the sustainability of contractor sources of adequately qualified training supervisors. If this is the preferred option, the Air Force must also establish policies that will ensure that contractor training supervisors can remain current on evolving tactics and munitions capabilities. To the best of our knowledge, none of these issues has been adequately addressed.

If, on the other hand, the preferred policy is to use active-duty supervisors in these training facilities, the Air Force must thoroughly analyze the scheduling issues that could result and determine the availability of qualified training supervisors who would also be required to supervise all the unit's live training. The same issues that prevent inexperienced wingmen from getting on the flying schedule could easily limit their simulator training as well. In the operational world that we envision for the near term, it may not be feasible for limited numbers of qualified pilots to be available to provide all the supervision that would be required for an integrated live and simulator training program and still remain within crew-rest constraints. If so, the Air Force will need to examine alternative sources for simulator training supervision. Simply changing the definition of an experienced pilot and declaring the operational training problem solved—without developing the efficient integrated training program and the aircrew management initiatives required to deal with the impending issues—could have serious training and operational consequences in the future.

Impending Issues

Chapter Four will document the training environment evaluations that we conducted and incorporate the results of our interviews and surveys from October 2002 through October 2003. These evaluations inspired our initial concerns about the adequacy of the 500-hour experience

definition for assessing a unit's health when determining whether the unit has enough pilots who are qualified to manage its training needs. These results also confirmed for us the advantages of coordinating and integrating the live and simulated training profiles available to pilots in a unit. We hope that the discussion that follows can also help to inform the process required to develop the integrated training program that we advocate.

Experience and Development Surveys

No objective, universally agreed-on method exists for measuring a pilot's actual level of experience.[1] For one thing, a pilot's experience may be meaningful only in an appropriate context—for example, an *experienced instructor pilot* is clearly distinct from an *experienced pilot*. Historically, even pilots who meet the 500-hour RDTM definition do not all reach each the same qualification level at the same time.

We therefore needed to find out what aspects of a pilot's training other than flying hours—such as upgrade level and training experience in DMO-capable simulator systems—should be counted in the determination of a pilot's experience level.[2] This led us to ask how pilots themselves determine when someone is "experienced," whether they expected a potential combat leader and a staff leader to have different kinds and amounts of experience, and whether they found DMO training an acceptable form of experience. To answer to these questions, we surveyed experts in fighter-pilot training to determine how well the current RDTM flying-hour definition of experience corresponds with how they evaluate a pilot's level of experience.

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[1] The apparently objective RDTM system for measuring experience in terms of flying hours is actually based on a subjective judgment of training experts about the criteria that should define an experienced pilot. We have spoken with several training experts who now believe these criteria do not give a good indication of the experience levels of the current crop of fighter pilots, illustrating the subjective nature of these criteria.

[2] *Upgrade level* refers to the position a pilot is qualified to fly in a formation and whether the pilot is a qualified instructor pilot. The levels of upgrade are *wingman*, *two-ship flight lead*, *four-ship flight lead*, and *mission commander*.

The survey used policy-capturing methods to determine the bases for expert pilots' judgments of other pilots' combat readiness and their readiness for staff positions (Anderson, 1981; Kline and Sulsky, 1995). These methods use statistical models to discover, or *capture*, how experts combine information in forming judgments. The combination rule that is the basis of these judgments represents the experts' *policy* as applied in making the judgment at hand. These methods are particularly well suited to the current research, in which one possible basis of an expert's judgment of a pilot's experience is the amount of training the pilot received in DMO-capable simulators. Fighter pilots may be reluctant to endorse the use of high-fidelity simulators in training if doing so could be interpreted as willingness to trade aircraft flying time for simulation training time. However, using policy-capturing techniques, experts are never explicitly asked to endorse such a trade-off, so their judgments are less likely to be tainted by this concern. With the surveys described in this chapter, policy-capturing methods were used to deduce the attitudes of training experts about the role of high-fidelity simulator systems and other training events in the development of experienced pilots.

We conducted two surveys over a one-year period, October 2002 to October 2003. The first survey was given to F-16 training experts at Hill AFB and represented a test of the policy-capturing methodology. The second survey, conducted with F-15C training experts at Langley AFB, Virginia, and Eglin AFB, Florida, reflected lessons learned from the first survey and included questions about training in DMO-capable simulator systems. DMO training was already part of the training curriculum at Langley. Results of the F-16 survey were used primarily to refine the survey structure and questions, so we will focus on the F-15 survey.[3]

The F-15 Survey

Goals

Using lessons learned from the first survey, we designed the second to give us a better chance of learning the informational basis for expert

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[3]   The appendix details the F-16 survey and its results.

judgments of pilots' experience in terms of readiness for a staff position and readiness for combat.

The Survey

At the core of the survey were 20 fictional pilot profiles, provided in an Excel file. This popular file format allowed email portability and permitted the respondent to set the survey aside to be continued later, if necessary. It also gave the respondent easy access to the instructions while taking the survey.

The Respondent Pool

We sent the survey to 40 F-15 training experts at Langley and Eglin AFBs. Of these, 20 completed and returned the survey, for a return rate of 50 percent. These individuals constituted a fairly representative sample of unit training experts. The number of respondents from the different positions sampled was nearly proportional to the total number of people in those positions.

Methods

We set up the program to generate detailed fictional pilot profiles randomly. Each expert evaluated a unique set of 20 different profiles. We tried to minimize the amount of guesswork about which details of each fictional pilot's background and training might influence the expert judgments of the pilot's experience.

Figure 4.1 is an example of one such fictional pilot profile as a respondent would see it.[4] The profile provides information about a pilot's overall training history and details about assignments before entering the current operational unit (see the upper left corner of the figure). The fictional pilots' experience ranged from having completed only undergraduate pilot training to having flown a different airframe and having spent time in a staff liaison tour. This information about a pilot's experience turned out to be a major determinant of expert judgments regarding the pilot's readiness for a staff position.

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[4] During their service at RAND as Air Force Fellows, knowledgeable Air Force fighter pilots reviewed the pilot surveys and developed data for the profiles.

Figure 4.1
Example Pilot Profile Display from the Survey of F-15 Experts

Pilot Profile

	Prior Experience			Current F-15C Assignment		Current Total Hours		
	1/93-9/96	10/96-9/99	10/99-3/02	6/02 - Present				
Position	IP	IP	Staff	Qualification	MC	F-15C Hrs:	1500	
MDS	F-15C	F-15C		Mos at Qual	5	Total Hrs:	1700	
MDS Hrs	700	600		Flying Hrs this assignment	200	‖‖‖ [◄ ►]		
Total Hrs	900	1500		Mos. In Wing	11			0

Last 6 months' training sorties

Sortie Position: MC = Mission Commander   *4 = 4 Flight Lead*   *2 = 2 Flight Lead*   WG = Wingman

	Months	6 months ago				5 months ago				4 months ago				3 months ago				2 months ago				Last month				SpinUp to Qual
		MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	0 ⬍
A/C sorties	BFM			2				4				1				2				1				2		
	ACM			2				2				2			1					3				2		0 ⬍
	ACT, 2vX			1				1				1			1					1				2		0 ⬍
	ACT, 4vX		2				1					1			2				3				3			0 ⬍
	Red Flag (LFE)	2	1	4																						0 ⬍
	Other LFE						1																			0 ⬍
	Red Air							2	1			3		2	2				1	2	1			1	2	0 ⬍
	AEF (Flying)																									0 ⬍
	Total A/C Sorties	2	3	9			2	9	1			8		2	6	2			4	7	1		3	7	2	
		MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	MC	4	2	WG	
DMT sims	ACM																							1		0 ⬍
	ACT, 2vX			1				1				1				1										0 ⬍
	ACT, 4vX		1	1																						0 ⬍
	LFE	1																	1				1			0 ⬍
	Total DMT Sims	1	1	2				1				1				1			1				1	1		
	Overall Totals	A/C	14	Sim	4	A/C	12	Sim	1	A/C	8	Sim	1	A/C	10	Sim	1	A/C	12	Sim	1	A/C	12	Sim	2	

RAND *MG597-4.1*

Information about the pilot's current status appears in the upper right corner of the profile (as shown in Figure 4.1) and included the pilot's current upgrade level (wingman, two-ship flight lead, four-ship flight lead, instructor pilot, or mission commander), primary aircraft flying hours, total flying hours, and months in the current unit. The lower portion of the profile provides the pilot's detailed six-month training history, with separate sections for aircraft and simulator sorties.[5] The display shows the number of sorties flown each month and the position (mission commander, four-ship flight lead, two-ship flight lead or wingman) in which the sorties were flown. The display shows eight types of aircraft sorties that represent the range of sorties flown in fighter training: BFM, ACM, two- and four-ship air ACT (two-ship ACT, four-ship ACT), Red Flag, other LFE sorties, Red Air, and AEF sorties. The display also shows four types of high-fidelity simulator sorties: ACM, two- and four-ship ACT ("ACT, 2vX" and "ACT, 4vX" in Figure 4.1), and LFE.

We asked the experts to make two judgments about pilot experience level, the first in terms of readiness for a staff assignment and the second in terms of readiness for combat. They were asked to judge readiness for a staff assignment by estimating the number of additional primary aircraft flying hours that would be required before the fictional pilot would be experienced enough to fill a nonflying staff assignment and to judge the combat readiness of each fictional pilot by estimating the number of spin-up sorties that would be required prior to being deployed to combat.

After responding to all the pilot profiles, respondents to the F-15 survey were asked to estimate numbers and types of training sorties (including simulation sorties) that a pilot should fly each month. The experts were asked to give their estimate of the optimal and minimal number of aircraft sorties (BFM, ACM, two-ship ACT, four-ship ACT, Red Flag, LFE, Red Air, and AEF) and of the optimal and minimal number of high-fidelity simulator sorties (ACM, two-ship ACT, four-ship ACT, LFE) that should be flown each month.

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[5] At the time of the survey, simulator sorties were referred to as distributed mission training (DMT) sorties.

Findings from the F-15 Survey

For the question of readiness for a staff position, a multiple linear regression was done with the dependent variable being the number of additional hours the pilot needed to be ready for a staff position. For the combat readiness question, a multiple linear regression was done with the dependent variable being the number of spin-up sorties needed to be combat ready.

Readiness for a Staff Position

Table 4.1 presents our survey results on the question of readiness for a staff position. These results show that expert judgments of pilot experience, in terms of readiness for a nonflying staff position, depend on more than just flying hours. The results of our analysis of expert judgments of a pilot's readiness for a staff position show that prior experience, which is highly correlated with the number of flying hours a pilot has, is one of the main determinants. That prior experience, not just flying hours, influences judgments about readiness for a staff position is indicated by the fact that the coefficients for PMA hours and total flying hours shown in Table 4.1 are not significantly different from zero, while the coefficient for prior experience is nonzero and significant at the 0.05 level.

A pilot's upgrade level also had a significant effect on judgments of experience in terms of readiness for a staff position. The main effect of upgrade level came from the distinction between wingman and all other upgrade levels. This result is shown graphically in Figure 4.2, which plots the average judgments about readiness for a staff position in terms of the additional PMA hours required as a function of upgrade level. The results in Figure 4.2 show that, on average, a wingman needed about 400 more PMA hours than a flight lead, instructor pilot, or mission commander to be considered ready for a staff position, whereas the flight lead, instructor pilot, and mission commander needed about the same number of extra PMA hours (400) to be considered ready for a staff position. These results suggest that, as long as a pilot remains qualified only as a wingman, he or she would never be

Table 4.1
F-15 Experience Survey Results: Readiness for a Staff Position

Regression Statistics			
Multiple R	0.450980681	Standard error	0.875334918
R^2	0.203383574	Adjusted R^2	0.182099929
Observations	270		

Analysis of Variation				
	df	SS	MS	F	Significance F
Regression	7	51.25266071	7.321808673	9.555862007	1.42187×10^{-10}
Residual	262	200.7473393	0.766211219		
Total	269	252			

	Coefficients	Standard Error	t-Statistic	P-Value	95% Confidence Lower	Upper
Intercept	−2.78	2.24	−1.24	0.22	−7.20	1.63
PMA	0.00	0.00	−0.66	0.51	0.00	0.00
Total	0.00	0.00	−0.79	0.43	0.00	0.00
PMA × upgrade level	0.00	0.00	1.02	0.31	0.00	0.00
Prior experience	0.41	0.20	2.08	0.04	0.02	0.79
Wingman	4.86	2.25	2.17	0.03	0.44	9.29
Flight lead	3.34	2.15	1.55	0.12	−0.89	7.58
Instructor pilot	2.26	1.71	1.32	0.19	−1.11	5.63

NOTE: The dependent variable in the regression is the estimate of the number of extra hours needed to be ready for a staff position. This judgment is based on information about the pilot's flying hours (PMA and total), upgrade level (wingman or flight lead or instructor pilot), and the interaction between these PMA hours and upgrade level. (The analysis did not include the interaction between total hours and upgrade level because it contributed nothing to the prediction of readiness for a staff position.) The estimates of the extra hours a pilot needed to be considered experienced were standardized within subjects. So, the regression factors out individual differences between subjects in how they estimate the hours needed for a staff position.

Figure 4.2
Additional Primary Aircraft Hours Required to Be "Experienced"
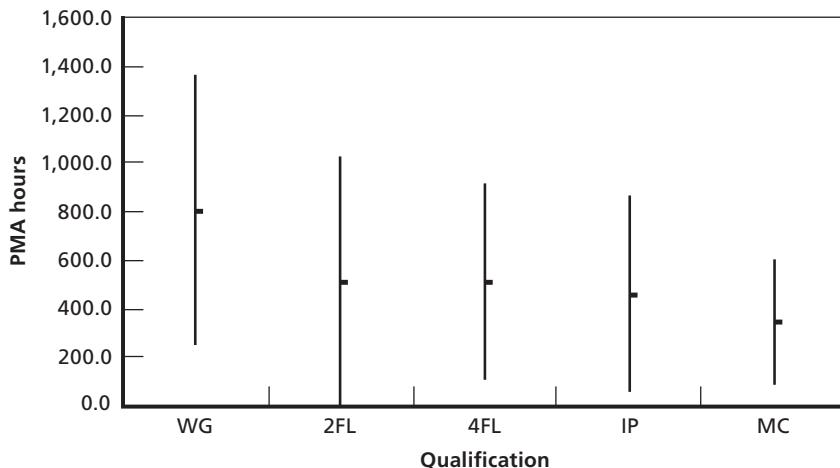
considered experienced, in the sense of being ready for a staff position, regardless of the number of primary aircraft hours flown. The results displayed in Figure 4.2 also suggest that a pilot must at least be a flight lead to be considered ready for a staff position.

One surprising observation based on the results in Figure 4.2 is that the respondents in this survey indicated that a pilot should have far more hours than RDTM specifies to be considered sufficiently experienced for a staff position (the conventional meaning of *experienced* from the RDTM perspective). The average number of PMA hours for the fictional flight leads, instructor pilots, and mission commanders in this survey was over 500, so the number of additional hours the experts recommended for these pilots to be considered ready for staff positions brought the average total hours to nearly 1,000, which is twice the RDTM requirement for pilots entering units after their initial upgrade training in a fighter aircraft. Clearly, the respondents to this survey wanted pilots, like themselves, to do a lot of flying before moving to a staff job. However, this result could indicate that pilots simply think they should do more flying at the time in their careers when they are in

flying units, not that the extra flying time is required to be successful in a staff position.

The results displayed in Figure 4.2 are also interesting because they suggest that there is a very strong feeling among pilots that the current RDTM system is sending pilots to staff positions before they are experienced enough. What the experts are saying in this survey seems to call into question some of the fundamental assumptions of the RDTM system. However, it may be that the additional number of flying hours these experts judge to be required to be experienced beyond the current RTDM requirement also reflects their recent experience with the quality of flying hours—a greater proportion of flying time spent "boring holes in the sky."

Readiness for Combat

Table 4.2 presents our survey results on the question of readiness for combat. We looked at how various aspects of training affected judgments of pilot experience in terms of combat readiness. The results of this part of the survey showed that training variables had a significant influence on judgments of combat readiness. The predictor variables in this analysis accounted for 36 percent of the variance in the judgments (see Table 4.2).

Training Variables. For this analysis, ten measures of training experience were used to predict judgments about pilot experience in terms of combat readiness. Judgments about combat readiness were again made in terms of the number of spin-up sorties required before deployment to combat; this assumes that the greater the number of spin-up sorties required, the less combat ready the pilot. The training variables used in the analysis included high-fidelity simulator training. The predictor variables were measured in terms of the number of the different types of training sorties flown. Our analysis of judgments about combat readiness included the following types of aircraft and simulator sorties:

Table 4.2
F-15 Experience Survey Results: Aircraft Proficiency

Regression Statistics			
Multiple R	0.602	Standard error	0.0.789
R^2	0.362	Adjusted R^2	0.335
Observations	270		

Analysis of Variation					
	df	SS	MS	F	Significance F
Regression	11	91.20443544	8.291312313	13.30359194	4.8902×10^{-10}
Residual	258	160.7955646	0.623238622		
Total	269	252			

	Coefficients	Standard Error	t-Statistic	P-Value	95% Confidence	
					Lower	Upper
Intercept	1.024	0.542	1.888	0.060	−0.044	2.092
Last month						
Aircraft						
BFM	−0.139	0.087	−1.599	0.111	−0.311	0.032
ACM	−0.210	0.066	−3.199	0.002	−0.339	−0.081
ACT	−0.261	0.038	−6.849	0.000	−0.336	−0.186
LFE	−0.156	0.026	−5.889	0.000	−0.208	−0.104
Red Air	0.019	0.054	0.353	0.724	−0.087	0.126
Simulator						
ACT	0.056	0.049	1.137	0.257	−0.041	0.153
LFE	−0.126	0.058	−2.159	0.032	−0.240	−0.011
First five months						
Aircraft	0.010	0.010	0.979	0.328	−0.010	0.030
AEF	0.021	0.010	2.017	0.045	0.001	0.042
Simulator	0.010	0.015	0.671	0.503	−0.020	0.040

NOTE: The dependent variable in the regression is the estimate of the number of spin up sorties required for combat readiness. The predictors are the number of sorties of different types that were flown in the last month prior to combat or in the first five months of the six months prior to combat.

- Aircraft sorties—the number of
  - aircraft BFM sorties flown in the last month prior to deployment
  - aircraft ACM sorties flown in the last month prior to deployment
  - aircraft ACT sorties (both two- and four-ship) flown in the last month prior to deployment
  - aircraft LFE sorties flown in the last month prior to deployment
  - aircraft Red Air sorties flown in the last month prior to deployment
  - all aircraft sorties, of all types, flown in the five months prior to the last month before deployment.
  - AEF sorties flown in the five months prior to the last month before deployment
- Sorties in DMO-capable simulator systems—The number of
  - high-fidelity simulator ACM sorties flown in the last month prior to deployment
  - high-fidelity simulator ACT sorties flown in the last month prior to deployment
  - high-fidelity simulator LFE sorties flown in the last month prior to deployment
  - all DMO-capable simulator sorties of all types, flown in the five months prior to the last month before deployment.

Results. Table 4.3 summarizes the results. The training variables used to predict judgments of combat readiness are listed in the far left column. The significance of a predictor is again given by the P-value, in the far right column. Significant predictors, with P-values less than 0.05, are shaded. One set of significant predictors of combat readiness consisted of the numbers of aircraft ACM, ACT, and LFE sorties flown in the last month prior to combat deployment. The coefficients for all these predictors are negative, indicating that the more of these sorties were flown in the last month prior to deployment, the fewer spin-up sorties were required. The P-values for these three predictors show that all are significant at the 0.01 level.

Table 4.3
Coefficients of Training Variables Used in Regression Analysis with Combat Readiness as the Dependent Variable

Type of Sortie	Coefficients	Standard Error	t-Statistic	P-Value
Intecept	1.024	0.542	1.888	0.060
Last month				
Aircraft				
BFM	−0.139	0.087	−1.599	0.111
ACM	−0.210	0.066	−3.199	0.002
ACT	−0.261	0.038	−6.849	0.000
LFE	−0.156	0.026	−5.889	0.000
Red Air	0.019	0.054	0.353	0.724
Simulator				
ACT	0.056	0.049	1.137	0.257
LFE	−0.126	0.058	−2.159	0.032
First five months				
Aircraft	0.010	0.010	0.979	0.328
AEF	0.021	0.010	2.017	0.045
Simulator	0.010	0.015	0.671	0.503

NOTE: Significant predictors, with P-values less than 0.05, are shaded.

DMO-Capable Simulator Sorties and Combat Readiness. The only other significant predictors of combat readiness in Table 4.3 were the number of AEF sorties flown in the five months prior to the last month before deployment and the number of high-fidelity simulator LFE sorties flown in the last month prior to combat deployment. The positive coefficient for AEF sorties shows that the more of these sorties that are flown, the more spin-up sorties are needed before combat deployment. This result is consistent with the opinion, often informally

expressed by pilots, that AEF sorties actually provide negative training experience.

Perhaps the most interesting result of this survey is the finding that experts see recent LFE sorties conducted in the high-fidelity simulator as contributing significantly to the development of pilot experience measured in terms of combat readiness. The negative coefficient value for simulator LFE sorties shows that, if more of these sorties are flown in the last month prior to deployment, fewer spin-up sorties are needed before deployment. Thus, without being asked directly about the role of high-fidelity simulators in fighter training, the experts' judgments show that they consider high-fidelity simulator LFE sorties, if flown in the month immediately prior to combat deployment, to make a significant contribution to aircraft proficiency, measured in terms of the combat readiness of fighter pilots.

The results of the survey suggest that the training that contributes most significantly to aircraft proficiency is that received in the month immediately prior to deployment. Both aircraft and high-fidelity simulator training contributes to aircraft proficiency if it is received during this period. However, it appears that the only kind of simulation training that was judged to contribute significantly to aircraft proficiency, if it occurs during this period, is LFE. In operational training, it is impossible to know in advance which month of a pilot's training will be the last month before combat deployment; the survey results therefore suggest that it would be worthwhile to have a pilot fly an appropriate number of simulated LFE sorties every month.

Type of Training and Experience

The survey results show that ACM, ACT, and LFE (Red Flag and other types of sorties) are the main contributors to the development of combat readiness. The results also show that certain types of sorties—AEF, in particular—actually reduce combat readiness. This result shows the potential need to distinguish between two types of experience: experience that prepares one for a staff assignment and experience that prepares one for combat. While our results showed that AEF sorties are negatively related to the kind of experience that makes a pilot combat ready, they

may be a plus for getting experience suitable for staff assignments, since knowledge of deployed operations is key to many staff jobs.

The results of the F-15 survey also demonstrated that high-fidelity simulator training itself, particularly training involving distributed multiship simulation exercises (LFE), contributes to the development of pilot experience. This is shown by the fact that the number of LFE sorties performed in simulators during continuation training in the month prior to deployment was judged to increase the pilot's combat readiness significantly. So, a mix of both aircraft and high-fidelity simulator sorties contributes to the development of experience in terms of aircraft proficiency.

We can get an idea of what constitutes an appropriate mix of aircraft and simulator sorties by looking at experts' ratings of the optimal number of different types of sorties that inexperienced pilots should fly to maintain their proficiency.

Optimal and Minimal Training Sorties

Figures 4.3 and 4.4 summarize the answers to the survey questions on the optimum and minimum numbers of sorties that should be flown. Figure 4.3 shows the average and standard deviation of the ratings of the optimal number of each type of sortie described in the pilot training histories: aircraft BFM, aircraft ACM, aircraft two-ship ACT, aircraft four-ship ACT, aircraft LFE (Red Flag and other LFE), aircraft Red Air, DMO ACM, DMO two-ship ACT, DMO four-ship ACT, and DMO LFE. The experts agreed that the optimum number of total aircraft sorties that should be flown each month was between 12 and 16, with the average being 14. The experts were also quite consistent (in terms of the small standard deviation of ratings around the average) about the numbers of different types of aircraft sorties that should be flown each month: three BFM, two ACM, two two-ship ACT, three four-ship ACT, two LFE, and two Red Air.

Respondents also agreed that the optimum number of high-fidelity simulator sorties that should be flown each month was between two and seven, with the average being about five. The respondents also agree that high-fidelity simulator sorties should be part of the optimum

Figure 4.3
The Optimum Numbers of Basic Sortie Types That Should Be Flown Each Month as Part of Continuation Training
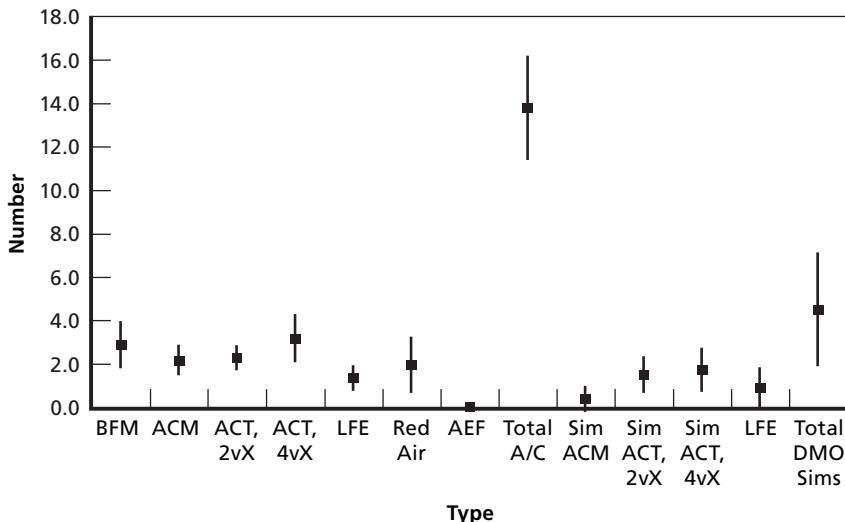
training sortie mix and were quite consistent in their ratings of the optimum numbers of different types of simulator sorties that should be flown each month: no ACM, two two-ship ACT, two four-ship ACT, and one LFE.

Figure 4.4 shows that the experts agreed that the minimum number of aircraft sorties for maintaining proficiency was between seven and 13, with the average near ten, four less than the optimum average. The main cuts in sortie types, relative to the optimum, were in aircraft BFM (cut by one sortie), aircraft ACM (cut by one sortie), aircraft four-ship ACT (cut by one sortie), and aircraft Red Air (cut by one sortie). The minimum number of high-fidelity simulator sorties is between one and five, with an average of about three. This result shows that sorties in DMO-capable simulator systems are considered an important enough part of training to be included even in the minimum sortie mix. The main cuts in simulator sorties relative to the optimum are cuts by one sortie each in DMO two-ship ACT and four-ship ACT.

Figure 4.4
The Minimum Numbers of Basic Training Sortie Types That Should Be Flown Each Month as Part of Continuation Training
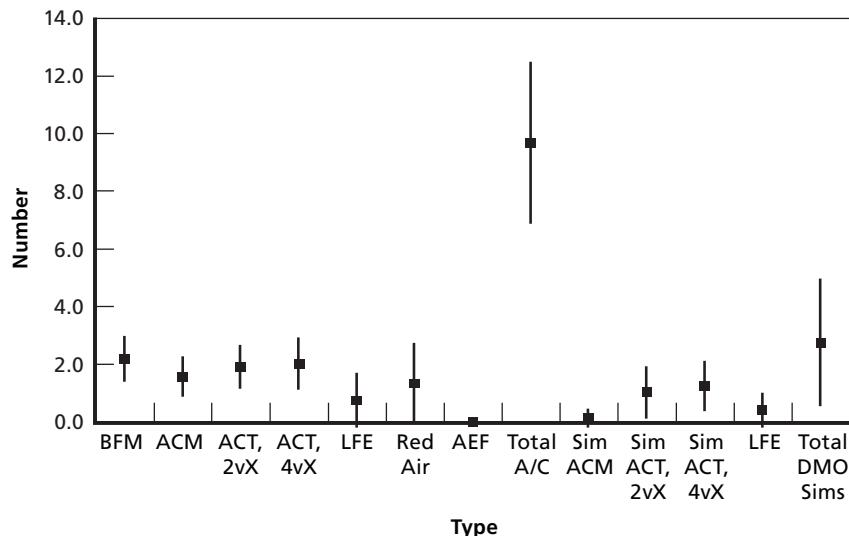
Insights into the Meaning of Pilot Experience

To be considered experienced in the RDTM sense of being ready for a staff assignment, a pilot must have upgraded at least to flight lead. Until a pilot has achieved flight-lead status, increasing flying hours produces very little increase in the perceived experience level of the pilot. Of course, this is consistent with the notion that, if a pilot does not achieve flight-lead status after a certain amount of time, the pilot probably does not have "what it takes," no matter how much time he or she spends in the cockpit. If feasible, increasing the speed and efficiency of pilot upgrades would increase the rate at which pilots could become experienced in terms of readiness for a staff position. One way to accelerate upgrades could be to use simulation to better prepare pilots for upgrade sorties, so that such sorties are more likely to be completed successfully. DMO-capable simulator systems could be used to provide the kind

of training needed to prepare pilots for the multiship upgrade sorties needed to move from wingman to flight lead and beyond.

These results also suggest that the type of training received—in terms of the types of training sorties flown—matters when it comes to the development of experience in the sense of aircraft proficiency. Advanced aircraft sorties and multiship high-fidelity simulator sorties make the greatest contribution to the development of pilot experience in terms of aircraft proficiency. These results suggest that providing an optimal mix of appropriate aircraft and high-fidelity simulator sorties could develop pilot experience in terms of aircraft proficiency. Experts agree that about 26 percent of the sorties flown in this optimal mix of sorties would be conducted in the high-fidelity simulators.

Conclusions and Recommendations

The research described in this report was motivated by concerns about the Air Force's ability to develop experienced pilots at a rate that not only maintains an appropriate balance of experienced and inexperienced pilots in operational fighter units but also prepares pilots to progress and develop the skills required to fill staff and supervisory positions. The problem of maintaining this balance will always exist in a stressed training environment, especially when experience is defined by a single flying-hour criterion and as long as the process assumes that continued development is assured once the 500-hour criterion is met. This assumption may no longer be valid when not enough flying hours are available to continue the development of experienced pilots at an appropriate rate. Changes over time in the *quantity* and *quality* of training available in the operational units have confirmed that the 500-hour criterion has not had consistent meaning for describing the training and combat capabilities pilots possess at the time they initially meet that criterion. At the same time, high pilot-production goals have generated overmanning and low experience levels in many fighter units. As the Air Force is seeking ways to respond to these problems, it may have become essential to decouple pilot absorption from continued pilot development, thereby generating a requirement to monitor the processes independently. Our surveys, conducted between October 2002 and October 2003, helped us reexamine the concept of pilot experience by looking at what factors determine how operational training experts judge what constitutes an experienced pilot in several distinct contexts.

What Is Experience?

The results of this research suggest that flying hours give only a rough approximation of what experts see as a pilot's actual experience level. To the extent that *experienced* means readiness for supervisory or staff positions, the main determinants in this context are the skills and qualifications required for the increased responsibilities pilots will face in these positions. These factors are highly correlated with flying hours, but our surveys showed that the RDTM definition does not effectively measure a pilot's qualifications for staff positions. Our experts judge that, for pilots to be considered ready for a staff assignment, they need nearly twice as many flying hours as would make them experienced according to RDTM standards. This casts a great deal of doubt on the validity of the previous assumption that meeting the 500-hour criterion automatically enables pilots to perform effectively or continue with their development in nonflying positions.

Survey results also show that the type of training received makes a big difference in terms of the development of the experience required to develop combat capability and prepare for combat operations. Live training sorties are the strongest contributors to reducing the spin-up training required to prepare for imminent combat operations in a specific theater, so flying hours will, in general, be highly correlated with the development of this essential experience. Not all flying hours are equal, however, in terms of their contribution to developing the experience that will be required. Indeed, live sorties with profiles from the high end of the training hierarchy contribute more to the preparation for combat than sorties from the low end of the hierarchy and much more than most sorties flown in support of a different AEF tasking. It should be noted, however, that our experts' judgments show that LFE sorties conducted in a high-fidelity simulator also make significant contributions to combat preparation. The survey results also suggest that an optimal regime for the development and maintenance of pilot experience for continuation training would include about 14 aircraft and five DMO sorties per month. Pilots appear to endorse considering certain types of high-fidelity simulator time when determining a person's qualification for certain duties.

Developing Qualified Pilots

The survey results suggest that pilots must accumulate a great deal more experience after they meet the initial 500-hour criterion if they are to continue to develop the qualifications required for meaningful staff assignments. This strongly suggests that the Air Force needs to manage the absorption and development processes separately because continued development is no longer ensured following the initial absorption period during their first operational flying opportunity.

The survey results also indicate that live training that is supported and augmented with appropriate high-fidelity simulator training profiles can be more effective in preparing pilots for imminent combat operations than live training alone. We would argue that the advanced simulators available in the MTCs need to be formally recognized and required in the applicable training directives. This would help ensure that the live training and the MTC training are properly coordinated to improve the overall training efficiency in operational units. This process can benefit substantially from the existing body of research on advanced simulator use that has been conducted at AFRL under joint sponsorship with ACC.

Unfortunately, integrated plans leading to more efficient training are only feasible in weapon systems for which the advanced simulator and MTC facilities are universally available. This will require resolving the existing funding and MTC supervisory issues in the DMO-capable facilities and keeping the operational flight program software for the MTCs consistent with that of the aircraft.

Nonetheless, absorption and developmental processes are still related because the successful completion of the former is an absolute requirement for the subsequent success of the latter. Their separate management, however, will require using new measures. The absorption process can perhaps be managed by modifying the existing RDTM definition to incorporate appropriate MTC training.[1] The developmental process, however, will require new criteria for the Air

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[1] According to Air Combat Command staff members (ACC/A3T), this is already being accomplished for aircraft weapon systems with appropriate MTC capability.

Force to measure pilot development in terms of the additional operational skills and qualifications required for these officers to perform staff and supervisory duties. The Rated Force Development Team and its associated combat air, mobility air, and special operations forces development panels, which was implemented to monitor the officer development process, could provide a framework to oversee this course of action, but rated officers may need to be reviewed earlier in their careers than they are now (which is as they reach eligibility for promotion to major) to ensure that they can receive the required second and subsequent flying assignments in their primary aircraft.

Survey Results from F-16 Pilots at Hill AFB

Goals

The first survey was specifically designed to evaluate how various training events affected the development of experience in F-16 pilots. This version of the survey did not include information about high-fidelity simulator systems because no DMO training was available to F-16 pilots at the time.

Methods

Each expert who participated in the survey was shown a set of 20 fictitious but realistic pilot profiles.[1] Each profile contained information about the pilot's overall flight training history and training sorties flown during the six months prior to the survey. Information about the pilot's training history included the pilot's upgrade level (wingman, flight lead, or instructor pilot), months at that upgrade level, number of primary aircraft hours, and total number of flying hours. Information about the pilot's training over the last six months included the number of sorties flown each month; the average duration of the sorties flown; and the total number of air-to-air, air-to-ground, and contingency sorties flown over the entire six months. Figure A.1 shows an example of the screen display for one pilot that a participant in the survey would see.

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[1]   During their service at RAND as Air Force Fellows, knowledgeable Air Force fighter pilots reviewed the pilot surveys and developed data for the profiles.

Figure A.1
Sample Data Screen for F-16 Survey

Proficiency Experiment						☒

Pilot 1 of 20

Pilot characteristics		Does pilot have sufficient operational experience for staff assignment?
Qualification	IP	
Mos. at Qual.	12	○ No
PMA hours	2140	⊙ Yes
Total hours	2140	

Training schedule

Most recent months

Month	1	2	3	4	5	6
Sorties/mo	6.0	6.0	3.0	3.0	0.0	0.0
ASD	1.0	1.0	1.0	1.0	0.0	0.0
Total hours	6.0	6.0	3.0	3.0	0.0	0.0

Number of different sortie types over six month period

Air to air	8
Air to ground	8
Contingency	2

◄ | | ►

0	Spin-up sorties required prior to combat deployment = 0	100

Stop		Next pilot > >

RAND *MG597-A.1*

The experts rated the experience level of the pilots described in each profile in two ways: first, in terms of readiness for a staff assignment and, second, in terms of readiness for combat. We did not ask directly whether a pilot described in a profile was experienced. We were concerned that the term *experienced* had been sufficiently connected to specific amounts of primary aircraft flying hours that, if we had asked whether a pilot was "experienced," the expert might make the judgment based solely on the RDTM criterion. Instead, we asked the experts to judge whether or not the pilot described in the profile was ready to be assigned to a nonflying staff position (one operational definition of *experienced*). A "yes" response (as marked in the upper right of Figure A.1) was taken to mean that the expert considered the pilot to be experienced. Experts also rated the combat readiness of a pilot by estimating the number of spin-up sorties the pilot needed

to fly before being deployed to combat duty. This estimate could be made in the bottom section of the survey screen. The more spin-up sorties needed, the less experienced the pilot was taken to be in terms of combat readiness.

The survey was sent to 34 F-16 training experts at Hill AFB and was completed and returned by 28, giving an 82-percent return rate. *Training experts* were defined as squadron commanders, squadron operations officers, squadron assistant operations officers, squadron weapons officers, squadron training officers, wing weapons officers, flight commanders, and instructor pilots. The respondents were representative of unit training experts in the sense that the number of respondents from these different positions was nearly proportional to the total number of people in those positions. The 28 experts evaluated a total of 560 pilot profiles—20 profiles per expert.[2]

Policy-capturing was used to determine how experts used information about a pilot's overall training history and training received over the last six months to form judgments about the pilot's experience in terms of readiness for a staff position and combat readiness.

Separate analyses were done on the yes-or-no judgments of a pilot's readiness for a staff position and the quantitative judgments of the pilot's combat readiness, but in both cases, the statistical analysis was based on all 560 pilot profile evaluations. For the question of readiness for a staff position, a logistic regression with PMA hours, non-PMA hours, and upgrade level (wingman, flight lead, or instructor pilot) as the independent variables was used to predict the yes-or-no judgments of the experts. For the judgment of combat readiness, multiple regression analysis was used with the number of spin-up sorties required as the dependent variable and the number of sorties flown each month, the average sortie duration each month, and the number of air-to-air and air-to-ground sorties as the independent variables.

Tables A.1 and A.2 provide the detailed statistical results for the F-16 survey. The discussion below refers to the results presented in these two tables.

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[2] The survey program generated the pilot profiles randomly, so each expert evaluated 20 profiles that were different from those of every other expert.

Table A.1
Detailed Results of Initial F-16 Survey of Experience as Readiness for a Staff Position

Experience	Odds Ratio	Robust Standard Error	z	P > |z|	95% Confidence	
					Lower	Upper
Non-PMA hours (A)	1.00	0.001	6.72	0.00	1.00	1.01
PMA hours (B)	1.00	0.000	7.14	0.00	1.00	1.00
Flight leader or instructor pilot (C)	2.41	3.219	0.66	0.51	0.17	33.13
A × C	1.00	0.001	2.32	0.02	1.00	1.00

NOTES: Logistic regression   Number of observations = 560
WALD chi^2 (4) = 106.68   Probability > chi^2 = 0.0000
LOG pseudolikelihood = –101.0228   Pseudo R^2 = 0.7320
Standard error adjusted for 28 clusters in rater.

Results

Factors that Affect Judgments of Readiness for Staff Positions

The dependent variable in the regression is the rating of whether or not a pilot is ready for a staff assignment. The judgment of experience is modeled using information about the pilot's flying hours (PMA hours and non-PMA hours), upgrade level (flight lead or instructor pilot, as opposed to wingman), and the interaction between upgrade level and PMA hours in the data. The judgments of readiness for a staff position were binary: 0 if not ready, 1 if ready for a staff position. As a result, a logistic regression analysis was done. Because each expert judge made multiple nonindependent judgments, a robust standard error estimate was used (Huber, 1967).

In predicting readiness for a staff position, upgrade level was initially coded as a dummy variable, with "instructor pilot" being the omitted value. However, initial results indicated that upgrade level should be collapsed into a single dummy variable of "flight lead or instructor pilot" versus "wingman." Table A.1 shows that the "odds ratios" of PMA hours, non-PMA hours, and the interaction of PMA hours and upgrade

Table A.2
Detailed Results of Initial F-16 Survey of Experience as Aircraft Proficiency

Regression Statistics			
Multiple R	0.38222543	Standard error	0.20830882
R^2	0.14609628	Adjusted R^2	0.13369841
Observations	560		

	Analysis of Variance			
	df	SS	MS	F	Significance F
Regression	8	4.09069589	0.511336991	1.7839766	1.5015×10^{-10}
Residual	551	23.90930417	0.04339257		
Total	559	28			

Sorties	Coefficients	Standard Error	t-statistic	P-value	95% Confidence	
					Lower	Upper
Intercept	−0.20	0.09	−2.17	0.03	−0.39	−0.02
During month						
Two	−0.16	0.08	−1.90	0.06	−0.32	0.01
Three	−0.02	0.05	−0.41	0.68	−0.12	0.08
Four	−0.04	0.05	−0.71	0.48	−0.13	0.06
Five	0.11	0.08	1.35	0.18	−0.05	0.27
Six	0.00	0.03	0.01	1.00	−0.05	0.05
Air-to-air	0.02	0.02	1.12	0.26	−0.02	0.07
Air-to-ground	0.02	0.02	0.96	0.34	−0.02	0.06

level are all statistically significant; unfortunately, the values are 1, which means that they are statistically independent of the "ready for staff duty" dependent variable. The box-and-whisker diagram in Figure A.2 does hint, however, that experts base their judgments about readiness for a staff position on both flying hours and upgrade level.

Figure A.2
**PMA Hours by Upgrade Status and Judged Experience**
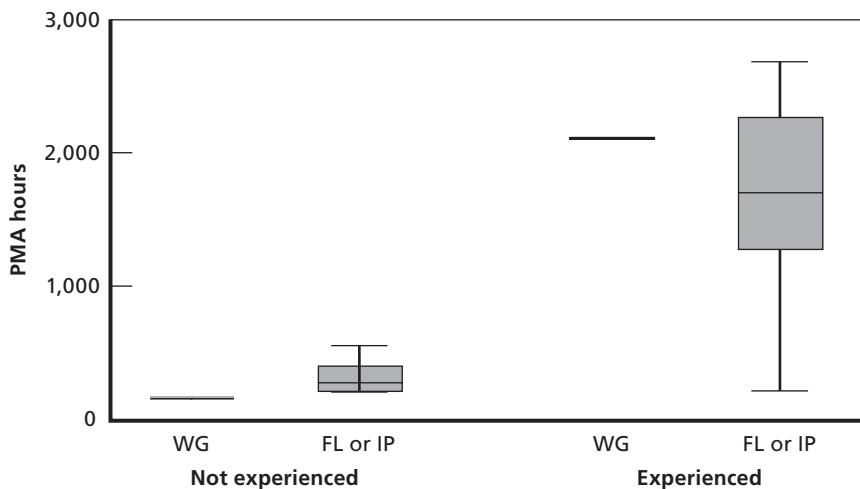
Figure A.2 provides median, maximum, minimum, and interquartile range for the number of PMA hours needed to be judged by the survey respondent as experienced enough for a staff position. The median number of PMA hours for a wingman to be judged experienced was over 2,000; the median number of PMA hours for a flight lead or instructor pilot to be considered experienced was about 1,700.

Factors That Affect Judgments of Combat Readiness
The dependent variable in the regression is the estimate of the number of spin-up sorties required for combat readiness. The predictors are the number of sorties flown in each month in the six months prior to the present, the number of air-to-air (and air-to-ground) sorties flown, and the experience level of the pilot.

The factors included in this analysis were all measures of training the pilots had received over the last six months: the total number of sorties the pilot had flown each of the immediately preceding six months and the total number of air-to-air and air-to-ground sorties flown in the six-month period prior to the present. The P-values in Table A.2 show that none of these training factors was a significant predictor of

combat readiness. Moreover, the R^2 value of 0.14 (shown as one of the regression statistics) indicates that the training factors included in this analysis accounted for only a small proportion of the variation in judgments of combat readiness.

A closer look at the data provided some insight into why none of the training factors was significant. Analysis of the judgments of individual experts revealed large individual differences across experts in terms of how information about a pilot's recent training history was used to judge combat readiness. These individual differences washed out any effects of training variables when the judgments of all experts were included in the policy-capturing analysis. We suspected that the differences among experts in terms of how they judged combat readiness might have resulted from their need to imagine facts about the fictional pilots described in the profiles that were not provided in the survey, with different experts imagining different facts. Therefore, we designed the next, and final, version of the survey to give more detail about each pilot and each pilot's training history. Also, because the final survey was to be given to F-15 training experts who had experience with DMO-capable systems as part of their training, the final survey also included information about the number of predeployment simulation sorties flown by each pilot in the MTC where such training occurs.

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